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An Economic Model
of the
Manufacturers' Aircraft Production
and
Airline Earnings Potential

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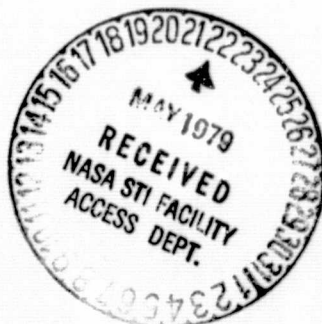
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AN ECONOMIC MODEL OF THE MANUFACTURERS'
AIRCRAFT PRODUCTION AND AIRLINE EARNINGS POTENTIAL
Volume III

FLIGHT TRANSPORTATION LABORATORY
DEPARTMENT OF AERONAUTICS & ASTRONAUTICS
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ABSTRACT

The principal focus of the Aircraft Production and Earnings Potential model is a behavioral explanation of the process of technological change in the U.S. aircraft manufacturing and airline industries. The general purpose of this model is to indicate: first, the principal factors which influence the aircraft (airframe) manufacturers in researching, developing, constructing and promoting new aircraft technology; and second, the financial requirements which determine the delivery of new aircraft to the domestic trunk airlines.

Once the model was fully specified and calibrated, the types and numbers of new aircraft were estimated historically for each airline's fleet. Examples of possible applications of the model to forecasting an individual airline's future fleet also are provided. From a purely methodological point of view, it should be noted that the functional form of the model is a composite which has been derived from several preceding econometric models developed on the foundations of the economics of innovation, acquisition, and technological change -- thus representing an important contribution to the improved understanding of the economic and financial requirements for aircraft selection and production. The model's primary application will be to forecast the future types and numbers of new aircraft required for each domestic airline's fleet.

1. BEHAVIORAL FOUNDATIONS OF THE MODEL

Traditional neoclassical microeconomic theory has been subjected over the years to a steady and occasionally heavy stream of criticism.¹ Among the more serious challenges to the neoclassical model are those that relate to its treatment of the processes of change. The prototypical neoclassical theory is one of full equilibrium under conditions of perfect and costless information -- to many observers, a narrow and generally inapplicable setting. As the theory has progressed in recent years, the meaning assigned to equilibrium has become less restrictive. The elements of a more advanced theory were set forth originally by Joseph Schumpeter,² who argued that, at the level of the individual firm, the crucial element is full recognition of the trial-and-error character of the innovation process. Despite the apparent importance of this consideration and of its prominent stature in the history of the discipline, very little empirical research has been done to incorporate

¹ Microeconomic theory refers to economic analyses of relatively smaller units in the economy (like profit maximization in a firm or concentration in an industry), in contrast the macroeconomic theory which pertains to economic analysis of larger aggregates (like gross national product or unemployment of whole countries). "Neoclassical" microeconomic theory refers to the stream of economic thought on production, distribution, efficiency and exchange that has characterized twentieth-century proponents of market-place solutions rather than large-scale government involvement in economic issues. Its etymology can be traced back to Alfred Marshall's Principles of Economics which was originally published in 1890. "Neoclassical" microeconomics' predecessor was "classical" economics -- the stream of economic thought that can be traced back to the writings of Adam Smith, Thomas Malthus, David Ricardo and the Mills. Contemporary microeconomic theory then is a composite of neoclassical economics and variations on maximization themes within the theory of the firm.

² Joseph Schumpeter, Business Cycles (New York: McGraw-Hill, 1939).

the trial-and-error concept into formal microeconomic models.³

The approach in this study is to illustrate a formal "evolutionary" model of technological change that can be applied to the aircraft manufacturers' industry in explaining the behavior of those firms in adopting particular types of aircraft technology for the domestic trunk carriers. At any given time, the behavior of an individual firm (like an aircraft manufacturer) is postulated to be governed by its current decision rules, which link its actions to various environmental stimuli. While these rules may be both quite complex and quite sensible, they are not typically the result of a deliberate optimization (such as profit maximization) over some precisely defined set of alternatives. The objective functions of the individual firm may yield considerable variation of behavior in a changing environment⁴ and may be approached from the viewpoint of the foundations established in the work on the "behavioral theory of the firm".⁵ As an example, applying the

³Recent exceptions are Richard R. Nelson and Sidney G. Winter, "Neoclassical vs. Evolutionary Theories of Economic Growth: Critique and Prospectus", Economic Journal, 84 (December 1974), pp. 886-905; and R.R. Nelson, S.G. Winter and H.L. Schuette, "Technical Change in an Evolutionary Model", Quarterly Journal of Economics, 90 (February 1976), pp. 90-118.

⁴James T. Kneafsey, The Economics of the Transportation Firm (Lexington MA: D.C. Heath and Co., 1974), Chapter 6. The objective functions for airline firms are probably multiple-attribute functions which may be subject to various forms of regulatory constraints. The fundamental difference between an analysis of airline firms and the traditional neoclassical model depends not so much on a constant and known objective function, like profit maximization, but on the fact that the domestic trunk carriers are regulated by an independent regulatory commission.

⁵Richard M. Cyert and James G. March, A Behavioral Theory of the Firm (Englewood Cliffs N.J.: Prentice-Hall, Inc., 1963). Much of the foundation of the behavioral theory of the firm and its doctrine of nonmaximization (known as "satisficing") can be attributed to the authors and to their colleagues at the (then) Carnegie Institute of Technology, especially Herbert A. Simon.

concept of "satisficing" from the behavioral theory of the firm to the aircraft manufacturers would suggest a set of interrelated objective functions that predict a range of optimal points of production, whereas the strictly neoclassical postulate of profit maximization would yield only a single optimal output.

Over a longer period of time, two types of dynamic mechanisms are assumed to be operative in the aircraft manufacturing industry. First, at the firm level, R & D policy changes may occur through processes of deliberate problem solving, perhaps involving some imitation of the observed decisions and successes of other firms. Or, second, technological change may "just happen" as particular capabilities in the firm improve through "learning-by-doing", deteriorate through disuse, or are adapted to shifting input (labor or capital) characteristics. This model will then treat the economic growth of the aircraft manufacturing firm as an adaptive, and not as a maximizing, process. In contrast, the neoclassical theory assumes universal access to the same technology, that firms choose optimally, and look to factor supply shifts for the explanation of productivity differences.⁶

The desirable feature in the manufacturers' model is its anticipated ability to explain, at least econometrically, the behavior of the aircraft

⁶As Nelson, Winter and Schuette have stated, "It is not a matter of different positions on the same isoquants; it is a matter of evolutionary change in the mix of firms of very different types.", op. cit., p. 93. Isoquants refer to contours on a production map where identical amounts of output (or quantities) and/or service can be produced by varying combinations of inputs (like labor and capital). On a two-dimensional production surface, differences among isoquants (which themselves are usually convex to the origin) reflect different levels of output that alternatively could have been produced by different combinations of inputs.

manufacturers in adopting, developing, and promoting both the products and the timing of new aviation technology. What factors can be postulated to determine the rate of technological change in this industry? On a priori grounds, one would expect it to depend to a large extent on the amount of resources devoted by the airlines, the manufacturing firms, independent inventors, the military, and the federal government to the improvement of the industry's technology. The amount of resources devoted by the government depends on how closely this industry is related to national defense, on the extent of the external economies to the airline industry generated by the relevant research and development, and on more purely political factors. The amount of resources devoted by independent inventors and by industry depends heavily on the profitability of their use and on internal industry political transactions. Comprehensive econometric studies⁷ indicate that the total dollars a firm spends on research, technology and development (R & D, or R, T & D) is influenced by the expected profitability of the R & D projects under consideration, and that the probability of its accepting a particular R & D project depends on the project's expected returns. Case studies of particular inventions and studies of patent statistics seem to corroborate this view.

In the aircraft industry, research into purely technological items (like the components of an aircraft, such as the supercritical wing) needs to be separated from the "products" of technology (or the outcomes of R & D that are produced and applied to existing aircraft). In the former case, many of the

⁷ See Edwin Mansfield, *Industrial Research and Technological Innovation: An Econometric Analysis* (New York: W.W. Norton and Co., Inc., 1968); and Nathan Rosenberg, "On Technological Expectations," *Economic Journal*, 86 (September 1976), pp. 523-555.

technology items are "placed on the shelf" and never find their way into application, for one reason or another. However, some of these items either are transferred into aircraft production or represent "spinoffs" for other products of aircraft technology. In the latter case, visible output is produced by the manufacturers and represents the key dependent variable that the research team modeled and estimated. For our modeling purpose, only those purely technological items which are converted (or can be immediately converted) into new or modified aircraft types were considered, especially on a year-to-year basis -- the unit of temporal variation in our postulated behavioral model. Thus, the specification of the model should capture the underlying determinants behind the joint decision of the manufacturers to produce aircraft and of the airlines to purchase them during varying conditions of aircraft retirements, fleet expansion, and capital markets.⁸

⁸ Carroll, Sidney L., "The Market for Commercial Airlines", Chapter 8 in Richard Caves and Mark Roberts' Industrial Organization (1976); Lloyd-Jones, D.J., "The Next Commercial Aircraft: What, When and Why as American Airlines Views It", Air Transportation Research Industrial Forum, San Francisco (May 9, 1977); Phillips, Almarin, Technology and Market Structure: A Study of the Aircraft Industry (Lexington, MA: D.C. Heath and Co., 1971); Ranfte, Robert M., "R & D Productivity - A Key Issue", Journal of Astronautics & Aeronautics, June 1976, pp. 50-56. Rosenberg, Nathan and Alexander Thompson, "Technological Change and Productivity Growth in the Air Transport Industry", Working Paper, Dept. of Economics, Stanford University (1977).

2. MODEL SPECIFICATION

One of the major issues faced by the aircraft manufacturers is how to determine the proclivity of individual airlines to purchase new equipment. The manufacturers must understand and estimate how rapidly the airlines are able to displace older aircraft and replace them with newer ones. This replacement process depends on two factors: the rate of imitation -- the rate at which the airlines begin to use newer aircraft, and the intrafirm rate of diffusion -- the rate at which a particular airline, once it has begun to use a newer aircraft, proceeds to substitute it for older ones. Note that the intrafirm rate of diffusion does not measure the speed with which the airlines begin to use newer equipment, but only its activity after the type of equipment has originally been procured. Together the rates of imitation and intrafirm diffusion determine how rapidly economic productivity increases in response to the existence of the newer aircraft and thus provide an incentive (at least potential) for airlines to replace portions of their existing fleets with newer aircraft.

The general model can be specified in three interrelated stages: first, a T equation which relates a technology variable (for example, the number of new aircraft of a particular type delivered during time period t) to a set of possible explanatory variables that reflect purely economic characteristics of the airline firms, manufacturers' performance, and external factors; second, an equation that can explain variations in the stocks or inventories of existing aircraft types in the fleets of airline firms (or alternatively, an inverse demand function for new aircraft); and third, an equation which explains variations in the profitability or cash flow positions of the

airlines -- who are the users of the new aircraft. The estimates of the second and third equations are postulated to become an additional argument (explanatory variable) in the first equation. Together, these two equations produce an estimate of the number of new aircraft of type j produced and delivered to airline i through time period t -- $T_{ij}(t)$ ⁹. The specific functional forms of the model are the following:

For any airline i (the subscript i will be omitted from the specification of the independent variables):

$$T_j(t) = f[\hat{\pi}_a(t, t-1, \dots), \pi_M(t, t-1, \dots), R_M(t, t-1, \dots) G^+(t+3), K(t, t-1, \dots), I(t, t-1, \dots), \bar{P}_j(t-1) \text{ and}] \quad (1)$$

$$P_{ij}(t) = \left[1 + e^{-(\alpha_{ij} + \hat{M}_{ij}t)} \right]^{-1} \quad (2)$$

where M_{ij} (the coefficient of time) can be separately estimated as:

$$M_{ij} = c_0 + c_1\pi_i + c_2L_i + c_3S_i + c_4C_i + c_5O_i + c_6F_i + \varepsilon_i \quad (2a)$$

and

$$\pi_i(t) = g \left[YLD(t), AVCOST(t), C(t), LFA(t), RPMS(t), RPMNS(t) \right] \quad (3)$$

⁹In addition, another equation that depicts the number of time periods that an airline must wait (or expect to wait) for aircraft delivery is given below as Equation (2a). This equation serves as a "control" equation to ensure that the estimates of the proportion variable in Equation (2) are meaningful.

In the above specifications, the interpretation of each variable is:

- T_j = product of technology (number of new aircraft of type j produced and delivered during time t)
- π_a = profitability of the airline firms using aircraft type j
- π_M = profitability of the manufacturer producing aircraft type j -- also labeled PLAG
- R_M = revenues of the manufacturer producing aircraft type j
- G^+ = expected growth of the industry (estimated three periods earlier)
- K = monetary stock (aggregate money supply) -- M2 definition: currency, demand deposits and time deposits in commercial banks
- I = interest rate -- long term corporate bond rate, as denoted by the Federal Reserve Board
- t = time period (also represents an explanatory variable in the $P_{ij}(t)$ equation)
- P_{ij} = proportion of the aircraft of type j in airline i 's fleet (where $i = 1, \dots, m$) -- also labeled PRO
- \bar{P}_j = weighted average of all the airlines' proportion variables (P_{ij})
- $\hat{}$ = estimated value (from another equation)
- π_i = the profitability of the i^{th} airline
- L_i = the time interval between when the first airline began using aircraft type j and the period when the i^{th} airline began to use it: a competition variable
- S_i = a size variable: number of employees of the i^{th} airline
- C_i = a liquidity measure: debt-equity ratio of the i^{th} airline at the time when the airline began to use aircraft type j
- O_i = a vintage variable: the percentage of the i^{th} airline's fleet that was five years or older when it began to use aircraft type j
- YLD = yield
- AVCOST = average cost
- LFA = load factor

ADV = advertising expenditures
RPMS = revenue passenger miles
RPMNS = non-scheduled revenue passenger miles
 ϵ_i = disturbance term

In our system of three equations, the dependence variable P and ϵ_i are estimated successively and their values inserted as arguments in the technology equation T . Variable M is merely part of a control equation used to authenticate and validate the consistency of equation (2).

3. RATIONALE FOR THE AIRCRAFT TECHNOLOGY EQUATION (T_j)

The process by which new aircraft are ordered by airlines and produced and delivered by the aircraft manufacturers has been fascinating to observe and analyze. The methods (some observers might say game-theoretic devices) used by the participants in the process are intricate and frequently subtle. A single error in ordering equipment can cost a manufacturer or an airline firm millions of dollars. Thus, the success or failure of a new aircraft order depends on a careful calculation and assessment by all participants of each airline's requirements, profitability, and anticipated traffic as well as a variety of external macroeconomic factors. The first portion of the manufacturer's model reflects these latter factors as they influence the distribution of aircraft deliveries by the manufacturers to the airlines (the T equation). The model's second portion is designed to explain the timing and diffusion of aircraft types within each airline's fleet (the P_{ij} equation).

The theory behind the aircraft technology (T) equation in the context of the expected signs of the regression coefficient, a priori, is the following:

- π_a = expected sign: positive, with lags. As the profits of the airline firms that are potential users of type j aircraft increase, the greater is the likelihood of increased orders for that aircraft.
- π_M = expected sign: positive, with no lag. Since the dependent variable represents delivered aircraft, and since airline payments for new aircraft represent on the average 67% of the delivered cost in the period that the delivery occurs (5% down payment on order date, escalating to 33% by delivery date, 67% remainder on delivery), it is expected that an increase in T will be accompanied by increases in the manufacturer's profit position, ceteris paribus.
- R_M = expected sign: positive, with lags. In order that revenues of the manufacturers could have increased in the past, aircraft sales would have to be providing a foundation and therefore a proclivity toward

increased market share for the range of aircraft in which type j aircraft competes. Thus, increased revenues implies a marketing advantage for the manufacturer of type j aircraft, thereby suggesting ever larger sales.

- G^+ = expected sign: positive, with forward lags. On the order date of aircraft type j, a value of the expected rate of growth in the industry is generated three years hence to coincide with the average delivery date: the higher the expected growth rate, the greater the deliveries.
- K = expected sign: positive. The higher is the money supply in real terms, other things being equal, the greater is the potential for airline firms to borrow funds in the money and capital markets in order to finance new equipment.
- I = expected sign: negative. The higher the interest rate, the more cumbersome is the financing package (and the greater the incentive for alternative uses of funds), and therefore the fewer deliveries will take place. While variations on interest rates are expected to be inversely correlated in general with changes in the money stock, the relative "stickiness" of interest rates should preclude a serious multicollinearity problem with the K variable.

Initial regression runs were conducted on the T model, even though some data on the T variable were not yet available. Early results suggested that the profitability and growth variables possess good explanatory power for B-707, DC-8, B-727, DC-9 and B-737 aircraft deliveries. These aircraft types were the only ones on which experiments were conducted, because the time series data for the wide-bodied aircraft are not sufficiently long. Additional data collection efforts would be necessary so that subsequent and alternative regression estimates can be made in the future. As indicated above, the complete T equation cannot be estimated until the $P_{ij}(t)$ equation has been fully calibrated. Once the complete model has been estimated and the results withstand the test of econometric scrutiny, the T estimate then becomes an important ingredient in explaining supply variations insofar as they ultimately affect the demand for air transportation.

4. RATIONALE FOR AND STRUCTURE OF $\bar{P}_{ij}(t)$

Essentially, the aircraft replacement model is an attempt to describe the behavioral process by which airlines decide to purchase new aircraft (and the timing of aircraft deliveries from its manufacturer). The submodel represents a "stock" or inventory item that is inserted into the T equation as an argument. The basic thrust of the submodel is an estimate of the relationship between the proportion of aircraft of type j in the i^{th} airline's fleet at any point in time. The remainder of "unfilled slots" for potential deliveries of aircraft type j to airline i in the future represents the potential demand for that aircraft type from airline i.¹⁰

Equation (2) above is simply a logit function relating $P_{ij}(t)$ to time. For example, taking natural logarithms of both sides of equation (2) yields

$$\ln \frac{P_{ij}(t)}{1-P_{ij}(t)} = \alpha_{ij} + M_{ij} t \quad (4)$$

Empirically, it is an easy matter to regress the left hand side of equation (4) against t to generate an estimate M_{ij} . This estimate is then used as the dependent variable in equation (3) and is further regressed against the independent variables on the right hand side. This procedure is done to insure that the M_{ij} term does indeed conform to the specification of equation (2). If the estimates of the coefficients do turn out to have the expected signs, and if the usual statistical properties adhere, then the submodel can

¹⁰ The justification for the submodel is straightforward, even though its complete derivation may be cumbersome. An alternate derivation is exhibited in Appendix C. The rationale for the airline earnings potential submodel is presented below in Section 6.2.3 and a lengthy discussion of its independent development and usage appears in Appendix B.

explain a substantial portion of the interfirm variation in each airline's rate of diffusion in ordering new aircraft and hence in offering another determinant to the manufacturer's timing of producing and delivering new aircraft.

5. DATA SOURCES

The number and types of aircraft deliveries are reported by the Civil Aeronautics Board (CAB) on both quarterly and annual series. Aircraft order data are more difficult to generate since the information is reported only by the announcements of the manufacturers and/or the airlines -- generally the information is reported in the Wall Street Journal or other trade publications. Since our preference was for consistency, the CAB delivery data were used in the analysis, assuming known distributions about the average lead times between order dates and delivery dates for each aircraft type.

The proportion data are merely derivatives of the fleet numbers as reported by the CAB. The profitability data are also reported quarterly by the airlines to the CAB -- our numbers were annual summations of the quarterly figures.

All other data were generated from published sources on an annual basis: manufacturer revenues and profitability from Standard and Poor, Inc.; industry growth rates from a combination of CAB and FAA sources; and macroeconomic data from the Council of Economic Adviser's report entitled "Economic Indicators".

6. MODEL CALIBRATION

6.1 Response Variable Quantification

The response variable (T) is defined as the number of new aircraft of type j produced and delivered in time t . For the purposes of calibration, new aircraft deliveries were summed for each airline to give an accumulated total of aircraft of type j in the fleet. This conveniently avoided the occurrence of zero deliveries.

Aircraft were grouped into three basic types by range, number of engines and the kind of routes which they could serve:

- a) Boeing 727-100 and Boeing 727-200 series;
- b) Boeing 707 and Douglas DC-8 aircraft; and
- c) Douglas DC-9 and Boeing 737-100/200 series aircraft.

The Boeing 720 was omitted from all groups in the basis of its unique characteristics with regard to performance, number of engines and range -- and its general deletion from existing fleets.

Historical data on fleet size of aircraft type j at year-end was collected for each U.S. domestic trunk airline from the data of first delivery to the end of 1975 inclusive.

6.2 Explanatory Variable Quantification

6.2.1 Proportion Variable

The computation of the proportion variable is discussed more fully in Appendix A. The value predicted for each year from the equation:

$$P_{ij} = \left[1 + e^{-\alpha_{ij} + \hat{M}_{ij}t} \right]^{-1}, \text{ the antilog of Eq. (4) above,}$$

was introduced as an explanatory variable in the manufacturer's model. Generally a two-year lag was applied to the proportion, \hat{P}_{ij} , such that an aircraft delivery in year (t) was in some way associated with the predicted proportion of the aircraft in the airline's fleet in year (t-2) - PR02. (In one particular case a four-year lag was more appropriate (PR04)). The two-year average lag time between order dates and delivery dates was further supported by the empirical evidence from B-727 deliveries which suggests an average lag from 1963-1976 of 2.3 years for all the domestic trunk carriers.

6.2.2 Profitability of Manufacturer

The profitability of the manufacturer producing aircraft type j was considered as a model variable. Pre-tax operating profit was taken from the Boeing Co. and McDonnell Douglas Corporation annual income statements. Various lags were tried, although usually a two-year lag (PIM2) provided the best statistical results.

6.2.3 Profitability of the Airlines

A model for predicting and forecasting the profitability of airline i to be used as an explanatory variable in predicting deliveries of aircraft type j is discussed more fully in Appendix B. Profitability was defined in that model as annual operating profit (\$) before deduction of depreciation allowances. In strictly accounting terms, this figure could be considered more as a measure of cash flow than profitability -- but it is regarded in the empirical sense as the major variable on which airlines base their aircraft ordering decisions.

The profitability of an airline (not only two years, but two, three and four years prior to delivery) was hypothesized to be appropriate in explaining acquisitions of new aircraft. The problem then arose of how to distribute the lagged values of profitability to make the variable most powerful in the manufacturer's model.

Distributed lags had been previously used by Elliott in his forecast and analysis of corporate financial performance using econometric models.¹¹ In one of his equations, he used a three-year Almon-weighted average of money supply and high employment government expenditures, with a second degree polynomial constraint. Almon-weights, however, can only be computed for equations where all explanatory variables are to be lagged.¹² Elliott

¹¹ J. Walter Elliott, "Forecasting and Analysis of Corporate Financial Performance with an Econometric Model of the Firm", Journal of Financial and Quantitative Analysis, March 1972, pp. 1499-1526.

¹² Z. Griliches, "Distributed Lags: A Survey", Econometrica, Vol. 35, No. 1 (January 1967) pp. 16-49.

side-stepped this problem by computing his weights on macro-economic data before inserting them into his equations. Unfortunately, no studies have been done on the lagged relationship between profitability and acquisition of major assets in other industries which might be applicable to our aircraft production potential model. As a "next best" approach two types of fixed weighting were tested:

Equal weights:
$$\frac{1}{3} [\hat{\pi}_{t-2} + \hat{\pi}_{t-3} + \hat{\pi}_{t-4}]$$

Declining weights:
$$0.5 \hat{\pi}_{t-2} + 0.3 \hat{\pi}_{t-3} + 0.2 \hat{\pi}_{t-4}$$

However, the results of testing the model with these weighting schemes showed that the method of weighting was not very critical to the significance of the profitability variable in the equation. Thus, we were able to use exogenously selected lags in each airline equation with increased confidence.

6.2.4 Airline Traffic Growth

The acquisition of new aircraft must to some extent be based on previous traffic forecasts conducted by the airlines. Individual airline forecasts could differ from the overall industry forecasts due to a greater optimism by airline forecasters and the individual airline route plans, though expansion in the latter is affected by CAB policies. The traffic growth variable should ideally, therefore, be the estimate of traffic growth actually made by the airline two or three years prior to delivery of the new aircraft.

It has been assumed in this study that airlines had projected their

traffic growth by a simple extrapolation of their previous five years' growth. While this approach may seem rather aggregate in the light of present day techniques, for the period under consideration it is a good approximation. It also places a relatively high weight on more recent events -- a factor which might be considered appropriate to management decisions at the time of ordering aircraft.

If any new aircraft were delivered in period (t), projections of traffic growth have been estimated at period (t-3) on the basis of the previous five-year trend. This average annual growth rate has then been applied to the (t-3) actual number of revenue passenger miles to arrive at the forecast number of RPMs for year (t). This variable was given the abbreviation GROW or G^+ . The same forecast number of RPMs was also applied to deliveries in period (t+1) to produce another variable GROW 1 which was used as an alternative explanatory variable.

6.2.5 Corporate Bond Rates

The average annual level of yields on corporate bonds (Moody's Aaa rating) was used as a proxy for the general economic climate at the time the decision to acquire the aircraft was made (Q12). As for the other explanatory variables, a two-year lag was considered to be best both from behavioral and expectational points of view.

6.2.6 Others

Other proxy variables for macroeconomic activity were tested such as "Money Supply" and real GNP. In addition, other measures of performance of the aircraft manufacturers were considered such as total revenues and current assets. Since our early results, however, confirmed the highly interactive theoretical foundation of some of these variables, these were eliminated as arguments in the equations during subsequent computer runs.¹³

6.3 Model Structure and Evaluation Techniques

6.3.1 Structure

The majority of the evaluation was performed on models which were linear in both parameters and variables of the type:

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2}, \dots, + \beta_n X_{in} + \epsilon_i.$$

This formulation appeared to be appropriate to at least all the Boeing 727 data and, although coefficients show changes in terms of absolute levels and not percentages, and cannot therefore be compared across airlines, further

¹³An existing model which uses some of these variables (e.g. monetary stock) is given in Yves G. Aureille, "The Outlook for the U.S. Airline Industry: An Econometric Approach", in Proceedings of the Workshop: Air Transportation Demand and Systems Analysis, M.I.T. Flight Transportation Laboratory Report R75-8 (August 1975), pp. 386-443.

refinement appeared unnecessary.

A log linear mathematical expression of the form:

$$Y_i = \beta_0 X_{i1}^{\beta_1} \cdot X_{i2}^{\beta_2} \cdot \dots \cdot X_{in}^{\beta_n} \cdot \epsilon_n$$

was tested for one of the Douglas DC-8 operators in order to try to improve the fit.

6.3.2 Evaluation Techniques

The models given above were calibrated using the ordinary least-squares technique. In order to find the minimum number of explanatory variables which maximizes the accuracy in prediction as well as providing the best behavioral analysis of the relationship, the Mallows " C_p " criterion¹⁴ was chosen.

Briefly, the C_p statistic is calculated for all combinations of explanatory variables and the response variable. It has a bias component and a random error component and is an estimate of:

$$C_p = \frac{1}{\sigma^2} \sum_{i=1}^n (v_i - \eta_i)^2 + \sum_{i=1}^n \sigma^2(\hat{Y}_i)$$

where

$$v_i = E(Y_i) \text{ according to the true relation}$$

¹⁴C. Daniel and F. Wood, Fitting Equations to Data, New York, J. Wiley and Sons, 1971, pp. 86-87.

$$\begin{aligned} \hat{Y}_i &= E(Y_i) \text{ according to the fitted equation} \\ \sigma^2(\hat{Y}) &= \text{variance of fitted value } Y_i \\ \sigma^2 &= \text{true error variance} \end{aligned}$$

Assuming that $\hat{\sigma}^2$ is a good estimate of σ^2 , it can be shown that:

$$C_p = \frac{SSE_p}{\hat{\sigma}^2} - (n - 2p)$$

where

$$\begin{aligned} SSE_p &= \text{sum of squares due to error} \\ \hat{\sigma}^2 &= \text{standard error of regression, all variables included} \\ p &= \text{number of variables included} \\ n &= \text{number of observations} \end{aligned}$$

The smaller the bias component in the fit, the closer the value of C_p approaches p . If C_p values are plotted against the number of parameters (p), the set of parameters whose C_p value is

- a) the lowest and
- b) closest to the line $C_p = p$

will be chosen as the set which minimizes both bias and random error. The "best" set of variables chosen under the C_p criterion should, however, also make good theoretical sense.

One of the assumptions of the ordinary least squares technique which originally was violated in several regressions in this study was that the explanatory variables should not be correlated among themselves. High multicollinearity leads to a significant increase in the sample variance of the coefficient estimators, resulting in inaccurate estimate of those coefficients and uncertain specification of the model with respect to

inclusion of that set of explanatory variables.

One way to correct for multicollinearity is to use principal components of the set of explanatory variables and make a linear combination of them in such a way that they capture as much of the variation in the response as possible.

The extent to which multicollinearity is present can be gauged by the condition number of X , or the largest condition index -- defined as the ratio of the largest singular value to the singular value of the i^{th} principal component. By deleting one or more principal components with high condition numbers, multicollinearity can be significantly reduced, though at the risk of reducing some of the fit if the linear combination deleted happened to be highly correlated with the response variable Y .

An example is shown below for the Eastern Boeing 727 model:

Original Model

$$T_p = 21.9 + 0.076 \text{ PR02} + 0.029 \text{ PLAG2} + 0.002 \text{ GROW}$$

(2.81) (1.90) (2.40)

$$R^2 = 0.982$$

$$\text{SER} = 4.93$$

		<u>Singular Value</u>	<u>Condition Index</u>
Principal Components:	1	53396.0	1
	2	367.7	145
	3	178.2	300
	4	1.5	36705

Multicollinearity could be significantly reduced by deleting the fourth principal component, whose condition index was proportionately larger than any of the others.

New Model

$$T_p = -6.45 \times 10^{-6} + 0.057 \text{ PRO2} + 0.048 \text{ PLAG2} + 0.002 \text{ GROW}$$

(2.13) (3.22) (3.62)

$$R^2 = 0.887$$

$$\text{SER} = 11.57$$

$$\text{Highest Condition Index} = 300$$

The trade-off between goodness of fit and accuracy of estimation of coefficients is illustrated by the drop in R^2 from 0.98 to 0.89 and increase in the standard error of the regression from 4.93 to 11.57, but an improvement in all T-statistics. One other effect of the procedure is to greatly reduce the constant term, giving perhaps a more realistic picture of aircraft orders at zero profitability and traffic.

Where principal component analysis has been performed, the highest condition index will be given alongside other goodness of fit statistics.

Where only the " C_p " criterion has been used, in no case did the simple correlation between any of the explanatory variables exceed 0.80. Although for forecasting purposes this rule of thumb was considered adequate, it should be mentioned that for analysis and control, there is still a small danger of two of the explanatory variables taken together being related to a third explanatory variable.

6.4 Boeing 727-100/200 Equations

Models were calibrated for the Boeing 727s for all U.S. domestic trunk airlines except one: Delta Airlines acquired its B-727 aircraft in 1972 as a result of their merger with Northeast, such that they did not take delivery

of the aircraft based on the same stimuli as the other trunk lines. Aggregating these two airlines' fleets was thought to present further complications in aggregating explanatory variables. For the remaining trunk carriers, the initial B-727 deliveries occurred in 1963 for United, followed by American, Eastern, National, Northwest, and TWA in 1964.

Both the proportion and profitability variables appear in all the equations given below with high t-ratios and relatively low Bonnferoni joint confidence intervals. Priority was given to developing a model where the effect of changes in explanatory variables both individually and jointly on the response variable could be estimated with a high degree of confidence.

1) American:

$$T = 4.46 + 1.21 \text{ PRO4} + 0.04 \text{ PLAG2}$$

(7.23) (6.62)

$$n = 12 \quad \bar{R}^2 = 0.98 \quad F = 219.5 \quad C_p = 3.42 \quad \text{SER} = 5.14$$

2) Braniff:

$$T = 1.22 \times 10^{-5} + 0.05 \text{ PRO2} + 0.02 \text{ PLAG(2)} + 0.03 \text{ Q12}$$

(6.50) (28.60) (4.63)

$$n = 10 \quad \bar{R}^2 = 0.94 \quad F = 35.2 \quad \text{Cond. No.} = 6 \quad \text{SER} = 4.77$$

3) Continental:

$$T = 2.23 \times 10^{-5} + 0.02 \text{ PRO2} + 0.02 \text{ PLAG(2)} + 0.002 \text{ GROW}$$

(1.36) (3.40) (2.69)

$$n = 9 \quad \bar{R}^2 = 0.95 \quad F = 39.4 \quad \text{Cond. No.} = 111 \quad \text{SER} = 2.44$$

4) Eastern:

$$T = -6.45 \times 10^{-6} + 0.06 \text{ PR02} + 0.05 \text{ PLAG2} + 0.002 \text{ GROW}$$

(2.13) (3.22) (3.62)

$$n = 12 \quad \bar{R}^2 = 0.89 \quad F = 21.0 \quad \text{Cond. No.} = 300 \quad \text{SER} = 11.58$$

5) National:

$$T = 5.06 + 0.04 \text{ PR02} + 0.005 \text{ PIM2} + 0.016 \text{ PLAG2}$$

(5.27) (1.68) (1.43)

$$n = 12 \quad \bar{R}^2 = 0.90 \quad F = 33.0 \quad C_p = 3.48 \quad \text{SER} = 4.08$$

6) Northwest:

$$T = -17.3 + 0.05 \text{ PR02} + 0.004 \text{ PIM2} + 0.02 \text{ PLAG2} + 0.04 \text{ Q13}$$

(2.43) (1.11) (4.36) (1.75)

$$n = 12 \quad \bar{R}^2 = 0.96 \quad F = 60.8 \quad C_p = 4.56 \quad \text{SER} = 4.15$$

7) TWA:

$$T = 1.52 + 0.20 \text{ PR04} + 0.011 \text{ PLAG2}$$

(10.14) (1.57)

$$n = 12 \quad \bar{R}^2 = 0.93 \quad F = 72.9 \quad C_p = 2.01 \quad \text{SER} = 6.48$$

8) United:

$$T = -3.3 \times 10^{-4} + 0.068 \text{ PR02} + 0.088 \text{ PLAG2} + 0.001 \text{ GROW1} - 0.095 \text{ Q12}$$

(4.32) (6.42) (1.79) (-2.76)

$$n = 13 \quad \bar{R}^2 = 0.89 \quad F = 16.4 \quad \text{Cond. No.} = 244 \quad \text{SER} = 19.52$$

9) Western:

$$T = -14.4 + 0.04 \text{ PR04} + 0.014 \text{ PLAG2} + 0.003 \text{ GROWI}$$

(2.04) (1.63) (5.17)

$n = 7 \quad \bar{R}^2 = 0.97 \quad F = 61.0 \quad C_p = 3.19 \quad \text{SER} = 1.07$

A summary of these results is given in Table 1 of coefficients, t-ratios, computed and critical F-ratios and Bonnferoni joint confidence intervals.¹⁵ The latter estimates the parameters $\beta_0, \beta_1, \beta_3$ jointly such that together they are significant at the 10% level.

The entries of Table 1 should be read across the rows for each airline. For example, in the case of American Airlines (AA), the significant variables are PR04 and PLAG2, or a four-year lagged proportion variable and a two-year lagged profitability variable. This model suggests that a unit change in the proportion of B-727 aircraft in American's fleet four years ago produced a 1.21 increase in the number of B-727 aircraft needed in its fleet now, ceteris paribus. Also, a unit increase in American's profitability (PLAG2) two years ago will be associated with a 0.044 unit increase in the number of B-727s in its fleet now, ceteris paribus. In each case involving either the PR0 or PLAG variable, the estimates of its values are extracted from Equations (2) and (3) discussed above in the "Model Specification" section.

Each of the airline's equations can be interpreted in a similar fashion by reading across the rows accordingly. Note that some airlines' equations contain more statistically significant variables than others -- but in every

¹⁵J. Neter and W. Wasserman, Applied Linear Statistical Models, Richard Irwin, 1974, pp. 146-147.

TABLE 1 SUMMARY OF B-727 REGRESSION COEFFICIENTS

		Proportion PRO2/4	Pft Mfgr PIM2	Pft Airline PLAG2	Traffic Projection Airline GROWTH	Interest Rates Q12/3	Computed F	Critical F $\alpha = 5\%$
AA	Coefficient t-ratio Intervals	1.210 ⁴ 7.23 ± 0.373	--	0.044 6.62 ± 0.015	--	--	219.5	4.3
BN	Coefficient t-ratio Intervals	0.046 ² 6.50 ± 0.016	--	0.020 28.6 ± 0.02	--	0.026 ² 4.63 ± 0.013	35.2	4.8
CO	Coefficient t-ratio Intervals	0.016 ² 1.36 ± 0.028	--	0.016 3.40 ± 0.011	0.002 2.69 ± 0.002	--	39.4	5.4
EA	Coefficient t-ratio Intervals	0.057 ² 2.13 ± 0.060	--	0.048 3.22 ± 0.033	0.002 3.62 ± 0.001	--	21.0	4.1
NA	Coefficient t-ratio Intervals	0.038 ² 5.27 ± 0.016	0.005 ² 1.68 ± 0.007	0.016 1.43 ± 0.025	--	--	33.0	4.1
NW	Coefficient t-ratio Intervals	0.050 ² 2.43 ± 0.046	0.004 ² 1.11 ± 0.008	0.020 4.36 ± 0.010	--	0.040 ³ 1.75 ± 0.051	60.8	4.1

TABLE 1 -- Concluded

		Proportion PRO2/4	Pft Mfgr PIM2	Pft Airline PLAG2	Traffic Projection Airline GROWTH	Interest Rates Q12/3	Computed F	Critical F $\alpha = 5\%$
TW	Coefficient t-ratio Intervals	0.205 ⁴ 10.14 ± 0.045	--	0.011 1.57 ± 0.016	--	--	72.9	4.3
UA	Coefficient t-ratio Intervals	0.068 ² 4.32 ± 0.034	--	0.088 6.42 ± 0.030	0.001 1.79 ± 0.002	-0.095 ² -2.76 ± 0.076	16.4	3.8
WA	Coefficient t-ratio Intervals	0.040 ² 2.04 ± 0.050	--	0.014 1.63 ± 0.022	0.003 5.17 ± 0.002	--	61.0	9.3

Interval = Bonnfironi joint confidence interval $\pm(1 - \alpha/4, n-2) S(b)$, where $\alpha = 10\%$.

2,3,4 = number of years lag prior to aircraft delivery.

case estimates of the proportion and profitability variables (with appropriate lags) appear in the main T equation. The principal reason for variation among the explanatory variables for different airlines is that each airline's route structure and organizational requirements are unique. The models merely portray the major factors affecting airline profitability and aircraft choice.

6.5 Boeing 707/Douglas DC-8 Equations

Models were calibrated for six U.S. trunk airlines for the Boeing 707 (all variants, but excluding the 720) and the Douglas DC-8 (all variants). Of the other four airlines, Continental retired their last Boeing 707 in 1973 and operated no DC-8s such that the aircraft group had no forecasting relevance. Western Airlines only operated B-707s for the past five years, their fleet size of five aircraft in each year showed no variation and thus the ordinary least squares technique was not considered appropriate. Braniff operated both aircraft types, posing some problems in aggregation, in particular for the manufacturer's profitability.

The final equations are presented below for American, Delta, and TWA. The results for Eastern, Northwest, and United will be discussed below.

1) American (707):

$$T = -44.2 - 0.012 \text{ PRO2} + 0.063 \text{ PLAG2} + 0.080 \text{ Q12}$$

$$(-0.95) \quad (20.40) \quad (8.66)$$

$$n = 17 \quad \bar{R}^2 = 0.99 \quad F = 567.4 \quad C_p = 3.75 \quad \text{SER} = 3.31$$

2) Delta (DC-8):

$$T = 0.001 + 0.108 \text{ PRO2} + 0.010 \text{ PLAG2}$$

(2.73) (1.35)

$$n = 17 \quad \bar{R}^2 = 0.69 \quad F = 9.7 \quad \text{Cond. No.} = 20 \quad \text{SER} = 7.91$$

3) TWA (707):

$$T = 9.00 + 0.107 \text{ PRO2} + 0.033 \text{ PLAG2} + 0.013 \text{ PIM2}$$

(3.72) (2.43) (1.73)

$$n = 17 \quad \bar{R}^2 = 0.90 \quad F = 47.8 \quad C_p = 2.44 \quad \text{SER} = 10.29$$

A summary of these results is given in Table 2 of coefficients, t-ratios, computed and critical F-ratios and Bonnferoni joint conference intervals. The percentage of variation in T "explained" by the Delta models was significantly lower than for either TWA or American, though for American a negative sign for the coefficient of PRO2 was unexpected.

The results for Eastern, although reasonable statistically, did not include profitability as a significant explanatory variable. Aircraft deliveries could, however, be explained in terms of the proportion variable with a four-year lag, manufacturer's profitability with a two-year lag and corporate bond yields with a three-period lag. Clearly aircraft orders for Eastern must in some way be related to both its profitability and expected traffic growth, though in a more complex way than was assumed in the model. The Eastern fleet of DC-8s has been reduced from a maximum of 40 aircraft in 1969 to only 5 in 1975, and since these five have since been leased to another airline, the need for forecasts disappears.

TABLE 2 SUMMARY OF B-707/DC-8 REGRESSION COEFFICIENTS

	PRO2	PIM2	PLAG2	GROWTH	Q12	Computed F	Critical F $\alpha = 5\%$
AA (707)							
Coefficient	-0.012	--	0.063	--	0.08	567.4	3.2
t-ratio	-0.95		20.40		8.66		
Intervals	± 0.027		± 0.007		± 0.021		
DL (DC-8)							
Coefficient	0.108	--	0.010	--	--	9.7	3.3
t-ratio	2.73		1.35				
Intervals	± 0.084		± 0.016				
TW (707)							
Coefficient	0.107	0.013	0.033	--	--	47.8	3.4
t-ratio	3.72	1.73	2.43				
Intervals	± 0.061	± 0.016	± 0.029				

The Northwest model also suggested variables other than those chosen as being more powerfully associated with aircraft deliveries. The proportion variable was particularly weak for two-, three-, and four-year lags, and may have been influenced by a rapid reduction in fleet size from 30 aircraft in 1972 to only 8 in 1975.

For United, a regression equation incorporating the proportion and traffic growth variables explained 78% of the variation in aircraft deliveries. As with Eastern, profitability was not significant.

6.6 Douglas DC-9 Equation

Delta was chosen for calibration of a DC-9 model since they were the only airline not included in the short/medium haul Boeing 727s. The result was not so good as the B-727 calibrations, particularly with respect to inclusion of the profitability variable which displayed very low t-statistics and was highly correlated with the proportion variable.

Attempts to remove some of the multicollinearity by principal component analysis did not give good results, and led to a reversal in the profitability coefficient sign. The model presented below, therefore, includes only proportion and corporate bond yield variables:

Delta Airlines:

$$T = -15.2 + 0.10 \text{ PR02} + 0.06 \text{ Q12}$$

$$(2.22) \quad (1.24)$$

$$n = 11 \quad \bar{R}^2 = 0.76 \quad F = 16.8 \quad C_p = 0.84 \quad \text{SER} = 13.30$$

7. MODEL RESULTS -- PREDICTED VS. OBSERVED

In this section of the report, we present the comparisons of our model predictions in relation to actual fleet numbers. It must be remembered that only narrow body aircraft have been analyzed to date, since the time series for wide-body aircraft are not yet sufficiently long.

7.1 Boeing 727

The model results have been tabulated both for individual airlines and for the U.S. domestic trunks as a whole. For the aggregate fleet size, model predictions were less accurate in the earlier years, when the U.S. fleet of this aircraft type was dominated by one or two large carriers. See Table 3.

Two effects tend to suggest that model predictions might not track actual data on a year-by-year basis. First, the timing of deliveries depends very much on the manufacturer's rate of production, excess capacity and international orders. The assumption of an approximately 2-year lead time between airline decision and delivery is a rough average over the period and will clearly depend on whether an order was made, say, in 1964 or 1973.

Second, the trend of actual fleet sizes will follow a stepwise path, whereas the model variables will suggest a more continuous time path. For example, a drop in profitability and slow-down in traffic growth in one year can be accommodated by using the existing fleet less intensively, rather than selling or leasing some of the fleet to other carriers and re-acquiring them

TABLE 3 MODEL RESULTS: OBSERVED VS. PREDICTED
BOEING 727 -- TOTAL U.S. TRUNKS

YEAR	OBSERVED	PREDICTED	PRED/OBS
1963	4	6	1.50
1964	94	108	1.15
1965	156	131	0.84
1966	248	226	0.91
1967	362	315	0.87
1968	455	425	0.93
1969	545	527	0.97
1970	568	542	0.95
1971	585	623	1.06
1972	609	640	1.05
1973	638	645	1.01
1974	651	635	0.98
1975	674	687	1.02

again when traffic picks up, which could be a costly way of matching capacity to traffic.

AMERICAN. Early year predictions are out of line for the reasons given above, while more recent results are good. The model predicts a rise in fleet size to 105 aircraft in 1971 due to good profitability two years previously and, perhaps, a faster rate of BAC-111 retirements estimated from the proportion model.

BRANIFF. Reasonably good results with a noticeable divergence between observed and predicted in 1973. Actual additions in that year totaled 13 aircraft compared with 3 predicted by the model. One possible explanation is the fleet standardization policy that this airline adopted around that time, which would override any natural growth in economic, traffic or profitability parameters.

CONTINENTAL. Relative latecomers to Boeing 727 operation, Continental's fleet size has increased steadily since 1973. The model predictions follow closely the observed pattern.

EASTERN. The model predicts a slower rate of introduction of these aircraft up to 1969. Over this period, the airline was also acquiring Douglas DC-9s which may be considered interchangeable with the B-727s on some of Eastern's routes. Thus, it is possible that the DC-9 model would overstate the rate of introduction of those aircraft. As in the case of American, the model predicted a relatively large increase in new aircraft in 1971 which did not occur.

NATIONAL. The fleet size for National increased to 38 aircraft in 1967 and has remained unchanged since then. Since 1967, any traffic expansion

TABLE 4 MODEL RESULTS -- OBSERVED VERSUS PREDICTED
BOEING 727 -- INDIVIDUAL AIRLINES

Year	American		Braniff		Continental		Eastern		National	
	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
1963	--	--	--	--	--	--	--	--	--	--
1964	18	28	--	--	--	--	25	18	7	10
1965	19	30	--	--	--	--	42	17	10	10
1966	41	34	12	14	--	--	53	37	13	14
1967	47	44	24	15	5	7	67	56	38	30
1968	80	76	27	28	13	9	75	69	38	34
1969	98	94	33	34	13	15	86	84	38	39
1970	98	100	39	42	13	14	101	96	38	41
1971	98	105	44	48	19	18	101	106	38	36
1972	100	101	50	56	22	24	109	114	38	38
1973	100	99	63	59	29	29	118	123	38	36
1974	101	101	67	63	33	33	114	116	38	37
1975	107	105	69	68	36	34	113	112	38	44

TABLE 4 Concluded

Year	Northwest		TWA		United		Western	
	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
1963	--	--	--	--	4	6	--	--
1964	3	6	16	18	25	28	--	--
1965	14	7	21	19	50	48	--	--
1966	24	28	22	25	83	74	--	--
1967	32	35	29	28	120	100	--	--
1968	36	43	44	56	142	110	--	--
1969	54	50	67	59	150	147	6	5
1970	56	52	67	61	150	129	6	7
1971	56	58	72	66	150	179	7	7
1972	56	56	72	68	150	141	12	12
1973	56	57	72	72	150	158	12	12
1974	55	52	74	78	151	138	18	17
1975	63	62	77	83	150	158	21	21

on National's routes has been taken up by increasing load factor, aircraft utilization, and the acquisition of Douglas DC-8s and later DC-10-10s. The model has to some extent taken these effects into account, mostly through the proportion variable.

NORTHWEST. The model predictions have closely followed actual fleet size, especially in recent years. Six new deliveries were, however, predicted for 1971, when none actually occurred.

TWA. The model forecasts additions to the TWA fleet in every year, whereas in three of the years no new aircraft were acquired. The rate of new deliveries was higher than predicted in earlier years and lower in the years since 1971.

UNITED. As the largest operator of this aircraft type, United's fleet has a large weight in the aggregate fleet size. United was the first to take delivery of this aircraft in 1963, and reached this present fleet size in 1969. The model results for United were not good, with actual United deliveries very much higher than predicted in the years 1966/67/68 and below predicted in 1971/72. The main reason for this imbalance is found in a paper¹⁶ giving the story of the United Airlines \$750 million order of new aircraft made in April 1965.

"To offset the delay in getting the small jet (Boeing 737), the Boeing Company was quite willing to deliver more B-727s in 1966 and 1967 so that United could offer the same quantity of jet service as if it had purchased DC-9s (with no delay). But this would have meant operating a more expensive airplane for a year and possibly ending up with more 727s than were needed."

¹⁶W.R. Nesbit, Airline Fleet Planning - United's \$750 Million Decision, from "Decision-Making Criteria for Capital Expenditures", 4th Summer Symposium Papers, American Society of Engineering Education, 1965.

WESTERN. The model results track very closely the actual deliveries from the time of introduction in 1969.

7.2 Boeing 707/Douglas DC-8

The model results for the narrow-bodied long-haul aircraft were generally inferior to those for the Boeing 727. The American and TWA models gave predictions which followed closely actual aircraft fleet size. The TWA model predicted a reduction in fleet size in 1971 of 16 aircraft which did not occur (the airline acquired two more), while the American model showed a run-down in these aircraft starting in 1972/1973 when it took place in fact a year later.

The Delta DC-8 model shows a steady increase in fleet size to 46 aircraft in 1975. In fact, Delta's fleet peaked in 1969 at 41 aircraft and declined between 1972 and 1975 to only 29 aircraft. The Northeast merger is a possible explanation of this divergence.

7.3 Douglas DC-9

The model predictions are given below alongside actual fleet size for Delta Airlines. Relatively poor results can be expected from a model which included only the proportion and corporate yield variables. In any event, the merger with Northeast in 1972 most probably affected aircraft purchases both prior to and since that time.

The fall in fleet size since 1972 was primarily due to the Northeast

merger and acquisition of 14 DC-9s (and 21 B-727s) from that company. The problems which would result from improving the model by pooling the Northeast and Delta data have already been discussed.

TABLE 5 MODEL RESULTS -- OBSERVED VERSUS PREDICTED
BOEING 707/DOUGLAS DC-8 -- INDIVIDUAL AIRLINES

Year	B-707				DC-8	
	American		TWA		Delta	
	Obs.	Pred.	Obs.	Pred.	Obs.	Pred.
1959	24	24	20	27	6	1
1960	23	22	27	25	6	1
1961	23	23	35	47	6	12
1962	23	25	43	53	10	13
1963	24	24	52	50	12	15
1964	27	27	65	50	15	17
1965	34	32	67	56	19	18
1966	40	46	81	83	20	20
1967	63	61	100	103	24	23
1968	91	89	111	105	39	27
1969	100	97	121	109	41	29
1970	98	103	102	110	41	32
1971	96	99	104	94	41	34
1972	98	100	103	98	41	37
1973	98	92	102	98	34	39
1974	90	89	91	105	34	42
1975	90	91	100	111	29	46

TABLE 6 MODEL RESULTS: OBSERVED VS. PREDICTED

Delta DC-9

Year	Observed	Predicted
1965	4	12
1966	14	12
1967	23	42
1968	60	48
1969	68	53
1970	73	59
1971	77	67
1972	77	76
1973	72	75
1974	70	76
1975	62	79

8. EXTENSION AND APPLICATION OF THE MODEL TO OTHER AIRCRAFT TYPES

The model to date has been calibrated on time series data for those generic aircraft types that satisfy two criteria: (1) the aircraft is still a prominent part of the trunk carriers' fleets; and (2) that the time series data be of sufficiently long duration to meet the inherent statistical and econometric requirements. In the above analysis, the following aircraft types meet these criteria: B-727, DC-8, DC-9 and B-737 aircraft.

Since the B-727 series aircraft is the overwhelmingly dominant airliner in the domestic fleet at the present time, it is very useful that our econometric model did capture its ordering and delivery process. This aircraft is also expected to increase in popularity in the future. On the other hand, the DC-8 and B-707 aircraft have been experiencing declining usage within the commercial fleets -- having been relegated to supplemental carriers or sold to foreign purchasers. The twin-engine commercial aircraft (DC-9 and B-737 aircraft) are expected to hold their own over the next decade. These comments, of course, will be altered by any new derivative aircraft being introduced commercially or by any substantial entry to the American markets by foreign manufacturers (like the A-300).

What about the wide-bodied aircraft? Here in the cases of the DC-10, L-1011 and B-747 aircraft, our time series to date unfortunately is not sufficiently long enough to meet criterion (2) above. As economic researchers, we need at least two more years of data for the B-747 and three or four more years of historical data for the DC-10 and L-1011 aircraft. Even so, we were tempted to determine if any relationships existed using the

current data series and concluded that the results were promising, despite the inability to make any statistical inferences. This area clearly offers exciting opportunities for the application of this integrated model during the next two or three years. Then the model could be used to forecast the total trunk carriers' fleets and to improve upon and supplement existing (largely judgmental) forecasts like those provided in Table 7.

Of course, a final area of extension of the model is to the international arena. The model then would need to be calibrated on data from foreign flag carriers as well as from charter operations. Once all these arenas are represented, a world-wide fleet of aircraft distribution could be forecast.

TABLE 7 FLEET ADDITIONS TO MEET 1976-85 TOTAL ASM REQUIREMENT:
AN EXISTING FORECAST

Type	12/31/75	1975-85 Changes		12/31/85
	Operating Fleet	Retirements	Additions	Operating Fleet
747	95	6	58	147
DC-10	121	-	161	282
L-1011	78	-	88	166
707-300B/C	179	141	-	38
707-100B	89	87	-	2
707-300	10	10	-	-
720B	23	23	-	-
DC-8-61/62	59	32	-	27
DC-8-20/50	85	85	-	-
727-200	379	-	239*	618*
727-100	380	257	-	123
DC-9-30/50	134	-	30	164
DC-9-10	27	27	-	-
737	84	-	-	84
L-188	15	15	-	-
Model X**	-	-	155	155
TOTAL	1758	683	731	1806

* Includes possible new generation aircraft in the 140 passenger size category.

** New generation aircraft assumed to be in the 185-200 passenger size category.

Source: Donaldson, Lufkin and Jenrette (1977).

9. AN APPLICATION OF THE MODEL FOR FORECASTING PURPOSES

While countless applications of the model can be performed in its use as a forecasting tool, this section of the report discusses briefly three cases. We have selected B-727 aircraft (because of its importance) as the generic type to be forecast for three different trunk carriers: American, United and Western. The target year is 1985.

The forecast results are displayed in Table 8. In the upper third of the table are the results for American Airlines. Here the significant variables are the proportion variable, lagged four periods, and the profitability variable, lagged two periods. In our narrative discussion above, Equation (2) was a model developed to forecast the proportion of B-727 aircraft in each airline's fleet, while Equation (3) was a model designed to forecast individual airline's profitability (cash-flow). In the present table, the actual data are displayed for 1975. In addition, since our time series terminated with 1975 data, we present a "forecast" for 1976 and show the comparison between the 1976 forecast and the 1976 actual numbers for the T-variable -- the number of B-727s in each airline's fleet. Finally, in the right hand column are the forecast numbers for 1985.

AMERICAN. The model forecasts 110 B-727 aircraft in American's fleet, a deviation of 4% from its actual 115 at year-end. For 1985, however, assuming that the proportion of B-727s in its fleet in 1981 is 0.60 (the four-year lag in PR04), and assuming that the airline's profitability in 1983 is \$184.7 million (the two-year lag embodied in PLAG2), the model forecasts a mean value of 158 B-727 aircraft required for American's fleet in that year. If there were a $\pm 20\%$ shift in American's profitability in 1985, then

TABLE 8 SELECTED MODEL FORECASTS OF B-727 AIRCRAFT IN THREE AIRLINES

Variable	Actual 1975	Forecast 1976	Forecast 1985
American			
P4	38.5	42.6	60.0
$\pi 2^*$	1219.2	1231.2	1846.8
T (number of B-727s in fleet)	107 (Actual 115)	110	175 (high) 158 (middle) 142 (low)
United			
P2	51.3	56.5	60.0
GROWTH**	22570	30393	60786
$\pi 2^*$	1904.8	2286.7	3355.1
Q12	7.8	9.0	9.0
T (number of B-727s in fleet)	150 (Actual 150)	185	404 (high) 329 (middle) 254 (low)
Western			
P4	11.3	14.6	30.0
$\pi 2^*$	576.7	609.3	914.0
GROWTH**	9001	8094	16188
T (number of B-727s in fleet)	21 (Actual 21)	19	61 (high) 48 (middle) 36 (low)

* In hundreds of thousands of dollars.

** In millions of revenue passenger miles.

its 1985 forecasts for B-727 aircraft would be 175 and 142 aircraft, respectively. Any other perturbations to the explanatory variable would be handled accordingly.

UNITED AIR LINES. The 1976 forecast of 185 B-727 aircraft is 185, off considerably from the airline's actual number of 150. However, UAL, Inc., does have on two orders at this time a total of 46 B-727-200 aircraft, for delivery completion at the end of 1979.

Since the model results were presented early 1977 to several airlines' representatives, including those of UAL, Inc., it appears likely that United hesitated in making its ordering decision in 1975 and 1976, due to the adverse economic conditions prevailing at the time. By the end of 1979, it is probable that the model forecasts and the actual number of B-727 aircraft in United's fleet will coincide. For 1985, United's fleet is forecast at 329 B-727 aircraft, utilizing forecasts of the four variables in United's T equation: proportion, growth, profitability, and interest rate levels. As is the case with each airline's model, the forecasts of the proportion variable and the profitability variable are calculated internally whereas the forecasts of all microeconomic variables are made exogenously. In its final form the growth variable forecasts will be taken from the aggregation of the regional-pair market forecasts embodied in our General Passenger Market Model, described in Volume II. The high and low forecasts of the T variable reflect, as in the case of American, a $\pm 20\%$ change in United's profitability in 1983.

WESTERN AIRLINES. In Western's fleet, our model predicts 19 B-727 aircraft for 1976 (compared with 21 actual). In addition, under the same ground rules pertaining to the assumptions and forecasts of the other

airlines' models, the 1985 forecast for Western's B-727 aircraft is 48 -- with a high of 61 and a low of 36, depending on the sensitivity of its profitability in 1983.

One interesting feature of this model is that a wide range of forecasting scenarios can be portrayed for any future year, assuming that forecasts for the exogenous variables (all those except the proportion, profitability, and growth variables) can be made. Since the airline decision with respect to aircraft acquisition does depend on both internal and external economic and technological factors, this model does manage to capture in the aggregate the relative importance of these factors.

10. CONCLUDING ISSUES

Understanding various aspects of the aircraft ordering decision process has been undertaken in the past almost entirely on the basis of simplistic forecasts which relied to a large extent on judgmental factors. Now that the aircraft manufacturer and airline industries have reached a mature stage in their respective developments, the need to use more advanced analytical tools as a guide to economic forecasting becomes all the more compelling. In this study, the M.I.T. research team has developed an analytical model which offers some promise in forecasting the distribution of aircraft among the nation's airline fleets. While the forecast of a specific airline's fleet for a given year in the future obviously contains certain amounts of unknown factors, the model does provide a solid mechanism and a scientific foundation on which forecasts can be made, even though possible future disturbances cannot be captured (except by soothsaying).

The model of manufacturers' aircraft technology and airline earnings potential presented in this study represents a unique endeavor to portray some important factors which influence both the airlines and the aircraft manufacturers in the joint decision of purchasing and selling new aircraft. The model results can also be interpreted as contributive factors to the supply (cost) side of airline markets in which air passenger demand is influenced by the types of aircraft technology available. Also, while the findings of the model have reflected current and historical patterns of the airline firms and the manufacturers, it is expected that the model could provide useful information on the impacts of incrementally new aircraft technology on airline demand variables.

Together with previous results, the model suggests that there exist important economic and technological analogues to the classic psychological laws that relate reaction time to the intensity of the stimulus. Profitability opportunities act as stimuli, from which the intensity of the airline firms' speed of response seems to be governed quite closely. With respect to the diffusion process of new aircraft technology, the econometric model also suggests both how rapidly the airlines begin to use new aircraft technology (subject to manufacturer production constraints) and how rapidly the airlines substitute newer aircraft technology for older equipment. In addition, the model depicts the economic conditions under which the purchases of newer aircraft by the airlines have been historically worthwhile and profitable endeavors. To this end, while the uses of the model for forecasting purposes may only indicate the appropriate magnitudes at this time, it is anticipated that future applications and refinements to this model will sharply define and predict the likely impacts of future developments in new aircraft technology.

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APPENDIX A

DERIVATION OF THE $P_{ij}(t)$ SUBMODEL FOR THE PROPORTION VARIABLE IN THE MANUFACTURERS' MODEL OF AIRCRAFT PRODUCTION AND AIRLINE EARNINGS POTENTIAL

The following submodel is an attempt to describe the process by which airlines decide to purchase new aircraft. If $A_{ij}(t)$ is the number of aircraft of type j owned by airline i at time t , if N_i is the number of older vintage (like piston engine, early jet) aircraft operated by the airline before it adopted newer technology, and if R_i is the number of older aircraft (indexed) replaced by a single newer aircraft, then it can be postulated that the total number of aircraft operated by airline i at time t , $T_i(t)$ is:

$$T_i(t) = N_i - (R_i - 1) A_{ij}(t) \quad (A-1)$$

Since the airline will employ N_i/R_i aircraft of type j when the fleet contains all j type aircraft, then there are $N_i/R_i - A_{ij}(t)$ places left to be filled with new aircraft at time t . Suppose, for example, that the A_{ij} were DC-9s and that at time t , airline i bought four of them. Suppose further that each DC-9 had replaced two Convair 580s ($R_i = 2$) and that the fleet size was 40, prior to the DC-9 purchases. Then the total number of aircraft of all types in the fleet at time t was 36 or $40 - (2-1)4$ according to Equation (A-1). In other words, four DC-9s had replaced eight Convair 580s, ceteris paribus. It should be noted that the R_i variable value is an empirically elusive measure, but, fortunately, its significance will dissipate during the derivation of the submodel.

Let Π_{ij} be the rate of return that airline i would obtain by filling one of these slots with a newer aircraft, $U_{ij}(t)$ be a measure of apparent riskiness at time t in making such an investment, S_{ij} be a measure of the size, and C_{ij} be a measure of liquidity at the time when the airline began to purchase the newer aircraft type j . Letting $W_{ij}(t)$ be the proportion of

unfilled slots that were filled with newer aircraft type j during the period, its functional form would be:*

$$W_{ij}(t) = f[\pi_{ij}, U_{ij}(t), S_{ij}, C_{ij}, \dots] \quad (A-2)$$

Alternatively, $W_{ij}(t)$ can be regarded as a measure of the latent demand for newer aircraft of type j and can be stated in terms of next period's deliveries:

$$W_{ij}(t) = [A_{ij}(t+1) - A_{ij}(t)] / [N_i/R_i - A_{ij}(t)] \quad (A-3)$$

To continue with the above example, assume that the deliveries of DC-9s in the next period will total two. Then $A_{ij}(t+1)$ equals six and $W_{ij}(t) = (6-4) \div (20-4) = 1/8$. In other words, 16 slots were available at the beginning of the period and two were filled during time period t. But since $U_{ij}(t)$ cannot be measured directly, assume that $W_{ij}(t)$ can also be written as:

$$W_{ij}(t) = f(L_{ij}, R_i A_{ij}(t)/N_i, \dots) \quad (A-4)$$

where L_{ij} is the time interval between when the first airline began using aircraft type j and the year when the i^{th} airline began using them, and where $R_i A_{ij}(t)/N_i$ is the proportion of slots in the i^{th} airline already filled at time t.

Inserting (A-4) into (A-2) yields:

$$W_{ij}(t) = f(\pi_{ij}, L_{ij}, R_i A_{ij}(t)/N_i, S_{ij}, C_{ij}, \dots) \quad (A-5)$$

*For the foundations of this analysis applied to other industries, see Edwin Mansfield, Industrial Research and Technological Innovation: An Econometric Analysis (New York: W.W. Norton and Co., Inc., 1968).

Assuming that $W_{ij}(t)$ can be approximated adequately by a Taylor's expansion of Π_{ij} , L_{ij} , ..., C_{ij} , that drops third and higher order terms, so that the coefficient of $\left[R_i A_i(t)/N_i\right]^2$ is essentially zero. The corresponding differential equation then can be substituted for the difference equation that results. Recognizing that, as we go backward in time, the number of firms having introduced the newer aircraft of type j must tend to zero, we have:

$$\lim_{t \rightarrow -\infty} A_{ij}(t) = 0$$

and this in turn yields

$$A_{ij}(t) = N_i R_i \left\{ \left[1 + e^{-(\alpha_{ij} + M_{ij}t)} \right] \right\}^{-1} \quad (A-6)$$

where

$$M_{ij} = C_1 + C_2 \Pi_i + C_3 L_i + C_4 S_i + C_5 C_i + \varepsilon_i \quad (A-7)$$

Finally, if $P_{ij}(t)$ is the proportion of the i^{th} airline's aircraft that are type j at time t , then

$$P_{ij}(t) = A_{ij}(t)/T_i(t) \quad (A-8)$$

Thus, by inserting equations (A-1) and (A-6) into (A-8) yields:

$$P_{ij}(t) = \left[1 + e^{-(\alpha_{ij} + M_{ij}(t))} \right]^{-1} \quad (A-9)$$

which states that the proportion of the airline's aircraft that were type j should be a logistic function of time, and that the parameter measuring the intrafirm rate of diffusion, M_{ij} , should be linearly related to Π_{ij} , L_{ij} , S_{ij} , and C_{ij} and any others that might seem appropriate. The model has then been tested using data from the Civil Aeronautics Board and Moody's

Industrial Classification Service. The value of $P_{ij}(t)$ then is inserted as an argument to the T equation and assists in explaining the variation in the number of aircraft delivered each time period. Equation (A-9) is simply transformed into its usual structure by taking natural logarithms of both sides of the equation:

$$\ln \left[\frac{P_{ij}(t)}{1 - P_{ij}(t)} \right] = \alpha_{ij} + M_{ij}t$$

This submodel is a unique attempt to measure the diffusion of new technology in the literature on the economics of technological change. As such, it is an aggregate method to depict the major factors which determine variations in the timing and diffusion of new technology. The submodel hopefully reflects the relative capabilities of individual airlines to add (and delete) different aircraft types from their fleets as economic conditions change. In this way the estimation of an annual proportion variable can contribute to a better understanding of when and how many new aircraft are purchased by the domestic airlines.

APPENDIX B

AN ANALYSIS OF AIRLINE PROFITABILITY

1. INTRODUCTION

Recent predictions have estimated that U.S. airlines will require \$60 billion in order to satisfy their equipment needs in the 1980's. While a carrier's decision to purchase new capital equipment is a function of a variety of factors, clearly their market performance has important consequences on capital budgeting decisions. Not only does an airline's profitability determine the amount of internal funds available for investment, but it also contributes to determining the financial risk of the firm and its ability to utilize debt and equity capital on favorable terms. The inability to generate funds, because of poor performance, can therefore severely limit the investment decisions of the carriers.

As a recent Air Transport Association of America (ATA) study states, "...based on past earnings, airlines will be unable to compete effectively with U.S. manufacturing enterprises for capital funds."¹

Investigation of corporate performance allows not only for determination of key factors in investment decisions, but also evaluation and examination of several variables that impact on the profitability of individual carriers.

The objective of this report is an identification of those factors that have been significant in determining the profitability of individual air carriers. The general methodology that has been followed centers on analysis, via econometric techniques, of selected operational, financial, and economic factors frequently cited as contributing to the success or failure of an individual airline. A brief description and discussion of the

most significant items is given in Section 3 while the econometric model is developed in Section 4.

Before either the significant factors or the model can be discussed, however, an understanding of the regulated market structure in which the airlines compete needs to be developed. This should include the unique aspects of airline economics that are often omitted when traditional microeconomic theory is applied to airline analysis. Coverage of air transportation economics will be made in Section 2 and will rely heavily on the work of R.W. Simpson and N.K. Taneja (both of MIT) and their course notes. While this discussion is not meant to be exhaustive, it should point to the complexities and correlation among factors that are important in their influence on a carrier's profits.

1.1 Reference

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2. AIRLINE ECONOMICS -- A BRIEF SUMMARY

The U.S. airline industry operates in an environment that is closely regulated by the Civil Aeronautics Board (CAB). As a result, many of the market structure traits that are normally determined by "free market forces" are instead the result of CAB regulation. Theories as to why such regulation was (and is) necessary are well documented and will not be covered here.¹

While this study is an examination of the influence of various managerial and regulatory decision variables on individual carrier performance, these factors are, quite naturally, altered in response to changing supply and demand characteristics experienced by each airline. Section 3 will discuss in more detail specific factors, such as advertising, aircraft utilization, that are management controlled, as well as the idiosyncrasies of demand (seasonality, density) that are to some extent controlled by the CAB in the context of their influence on carrier performance.

However, as a basis for that later discussion, this section will cover the fundamental components of an airline's demand and costs. While the final analysis will involve an evaluation of performance in terms of system variables, this section will discuss demand and costs as they exist at the market and network level. As we shall see, demand exists for a given market, while supply and hence costs are the result of decisions made with regard to a system of markets or a network. Many of the points to be made are drawn from a recent discussion of these factors by R.W. Simpson of MIT.

2.1 Nature of the Product

An airline produces a set of flights throughout the system of routes (or city pairs) it serves. Unlike many products but common to services, airline output cannot be inventoried or stockpiled for later use. When a flight departs a given location, those "seat-departures" that are not utilized are lost forever. As a result, strikes, for example, are particularly damaging since demand cannot be satisfied by drawing down inventories. While the carriers have organized to minimize the impact of labor stoppages,³ strikes have a major impact on the carrier's market performance.

Without the ability to inventory output, carriers are faced with the need to either (1) expand their fleet and personnel to satisfy peak demand, (2) reduce schedules in one market so that extra traffic can be accommodated in a second city pair, or (3) maintain the fleet and schedules at present levels and allow the extra traffic to move to the competition. Alternatively, differential pricing has been used with varying degrees of success in attempting to smooth the distribution of demand throughout the day or season.

2.2 Airline Costs

It is generally accepted that airline costs can be separated into three major categories. The first, flight operations, covers the cost of flying the aircraft, i.e., crew, fuel, maintenance and ownership expenses. These

costs can be related to the number of hours flown (either block or flying hours), or to the number of seat miles of output, which takes into account the actual revenue earning potential of the aircraft.

As can be seen in Table 2.1, operating costs per block hour vary considerably for different aircraft types. This variation is reduced when aircraft size and speed is reflected in the cost per seat hour ratios.

Large reductions in seat mile aircraft costs resulted from the introduction of larger and faster jet aircraft in the 1960s. This in turn ensured a period of falling fares and total market expansion, which meant that the earnings potential of the more productive aircraft could be fully realized. The trend towards a greater number of seats per aircraft continued into the seventies, though, with fuel and labor costs eroding aircraft productivity advantages and causing fare increases, a situation of overcapacity gradually developed.

"For most of the 1960's, airlines were able to counter the adverse effects of inflation by transforming their fleets from propeller-driven to more efficient jet transports. It would be hard to exaggerate the cost benefits that jet engines meant for airline economics. But today, with most of the conversion to jet aircraft complete, these benefits have run out. Inflation has overtaken them and, in consequence, the industry is suffering." 4

A plot of total operating expenses vs. time clearly shows the steady decrease in costs as the jets were introduced (see Figure 2.1).

One additional characteristic that impacts on the flight costs is the design range of each particular aircraft. When an aircraft is operated at its design range, the payload it can carry, and hence the revenue it can generate, is at a maximum. However, if the aircraft flies further than its

TABLE 2.1 OPERATING COSTS

	Cost/Hr (\$)		Seats		Cost/Seat Hr		Avg Stage Length	
	1968	1975	1968	1975	1968	1975	1968	1975
B707-100	645.79	1167.47	126.7	130.6	5.10	8.94	1099	868
B707-300C	596.45	1241.94	135.8	144.4	4.39	8.6	978	1082
B727-100QC	515.62	950.61	95.1	99.7	5.42	9.53	509	585
B727-200	495.57	985.04	128.6	126.6	3.85	7.78	545	489
B737-200	387.97	900.03	95	95.7	4.08	9.40	193	301
DC-8-50	666.91	1203.11	134.1	133.9	4.97	8.99	910	754
DC-8-61	744.51	1442.39	196.6	192.6	3.79	7.49	1094	896
DC-9-10	424.37	829.85	69.9	70.2	6.07	11.82	287	392
DC-9-30	427.56	745.92	90.1	90.1	4.75	8.28	283	342
B747	1829.68 (1970)	2769.39	341	352.6	5.36	7.85	2097	1796
L-1011	1501.80 (1972)	2128.21	213.7	242.3	7.02	8.78	1237	882
DC-10	1173.57 (1972)	1889.21	224.6	233.1	5.22	8.10	1067	1187

Source: U.S. Civil Aeronautics Board Aircraft Operating Cost and Performance Reports

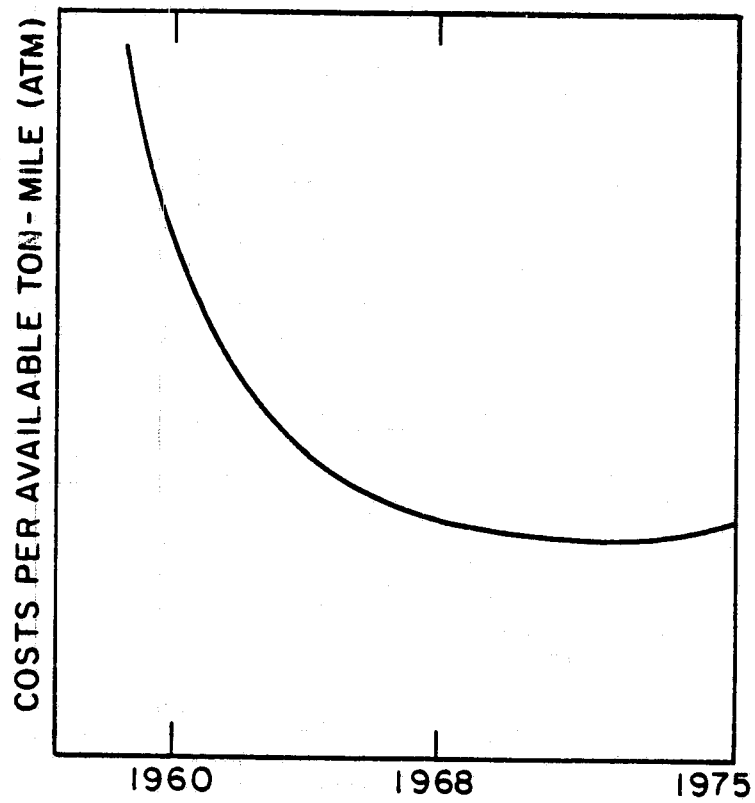


Figure 2.1 Cost Trend

design range, payload must be reduced to accommodate the additional fuel required. This not only reduces revenues, but increases costs. Likewise, when a long range aircraft flies a short haul route, the operating costs are generally higher than they would be if an aircraft of short range design were utilized.

Since an airline operates over a variety of stage lengths (with equally diverse traffic densities) it is impossible to match aircraft design range with stage length on every segment. Consequently, a carrier's system-wide operations are a compromise between routes, demand, and expected traffic growth on the one hand, and the design range and capacity of the aircraft in the existing fleet on the other. A carrier's ability to match these two factors can have considerable impact on their profitability, and decision to replace or expand their fleet.

The second major category of costs are labeled ground operating costs and include the expenses of refueling, dispatching, aircraft servicing, reservations and sales, baggage handling, and passenger boarding. Ground costs can be particularly significant if a station only serves one or two daily or weekly flights. In such instances, the carrier still requires certain minimum ground facilities regardless of the low level of operations. The obvious consequence is that an airline serving many remote, low density airports can be faced with inordinately high ground operating costs. While certainly not as large an expense as the flight costs, ground handling operations do at the same time require considerable investment in capital and labor that cannot be divided into fractional parts and must be maintained

at levels necessary to accommodate short-run peaks in aircraft arrivals/ departures. In some cases, however, carriers lease, or subcontract, certain items of equipment or use part-time personnel to handle these peaks in demand. Nevertheless, the ground support requirements are no small matter and can be aggravated by the number of aircraft types that operate at a given location. While some commonality does exist, an aircraft tow tractor, for example, may or may not be capable of being used on both a 727 and 747. If daily operations included both aircraft types, theoretically two tractors would be required.

An additional factor which can cause costs to far exceed normal expectations is the impact of the introduction of a new aircraft type into a carrier's fleet. During a so-called "break-in" period, ground handling time, servicing time, station maintenance operations, and aircraft handling are often less polished and subject to less efficient work as mechanics, baggage handlers and others learn the peculiarities of new aircraft types. This was a particularly pronounced phenomenon when the widebody aircraft were introduced in the early 1970's.

The third category of costs is the system operating or overall costs. These expenses consist of equipment depreciation (other than aircraft), general administrative costs, promotional and advertising costs, and ground maintenance. As these expenses are independent of the aircraft type used or the number of miles or hours flown, they have often been the focal point of intense managerial action to reduce overhead expenses without significantly reducing output. With costs continuing to rise, this area

has been a prime target for cost reductions as carriers attempt to maintain their financial strength.

It is important to remember, however, that for the most part, costs are fixed; a flight that is cancelled will save only the cost of fuel and oil, and landing fees, since schedules and crew expenses are pre-negotiated and ownership costs continue even if the aircraft never flies. Consequently the industry is one of high operating leverage resulting from the presence of large fixed costs. This results in two important facts: (1) the breakeven point or the point where revenues cover total costs is much higher than if fixed costs were lower, and (2) profits are larger, once the breakeven point is reached, than would be true with lower fixed costs.

2.3 Airline Demand

The demand for air transportation is derived from the fact that individuals are interested in moving between two locations. As such, air travel is not consumed in and of itself, but as a means to an end. Consequently, air carriers must compete in terms of price and quality of service with the other modes of transportation that are available (bus, auto, rail) to satisfy this desire for travel. Clearly, the advantages of air travel, namely speed and relative price, are the most pronounced on long haul markets where auto travel is less feasible.

When considering a particular mode of transportation, the total trip time should be represented by the "door-to-door" time. In the case of air travel, this includes: (1) the time to reach the airport, (2) the time

waiting for departure, (3) the actual airborne flight time, (4) the wait time after arrival for baggage, and transferring to another mode (bus, car, taxi) and (5) the travel time from the airport to the final destination. As the length of haul is decreased, the amount of time spent in actual flight becomes a much smaller percentage of the total. Airlines are aware of the impact of time on the travel choice and selection of carrier by passengers, and schedule in such a way that the time waiting for a departure is reduced to levels consistent with trip distance and market density. A greater number of departures not only increases demand by reducing wait time but, by increasing the probability that a seat will be available, induces more passengers to consider air travel. In general, it is thought that when annual average load factors on scheduled services rise to a level significantly above 60%, passengers will be unable to reserve seats at peak periods. Figure 2-2 illustrates the impact of frequency on demand for three stage lengths.

Total trip time is one of several variables that, as Simpson states, determine the quality of service offered by a particular carrier. Among the other service quality factors are the following:

(a) Trip Reliability -- This factor includes the probability of obtaining a seat, the probability of cancellation and the probability of on-time departure and arrival. Indirectly these factors relate to the airlines' perception of how highly its customers value their time and the impact of possible delays, either for scheduling or operational reasons, or their choice of carrier.

(b) Trip Comfort -- This factor involves the basic on-board services

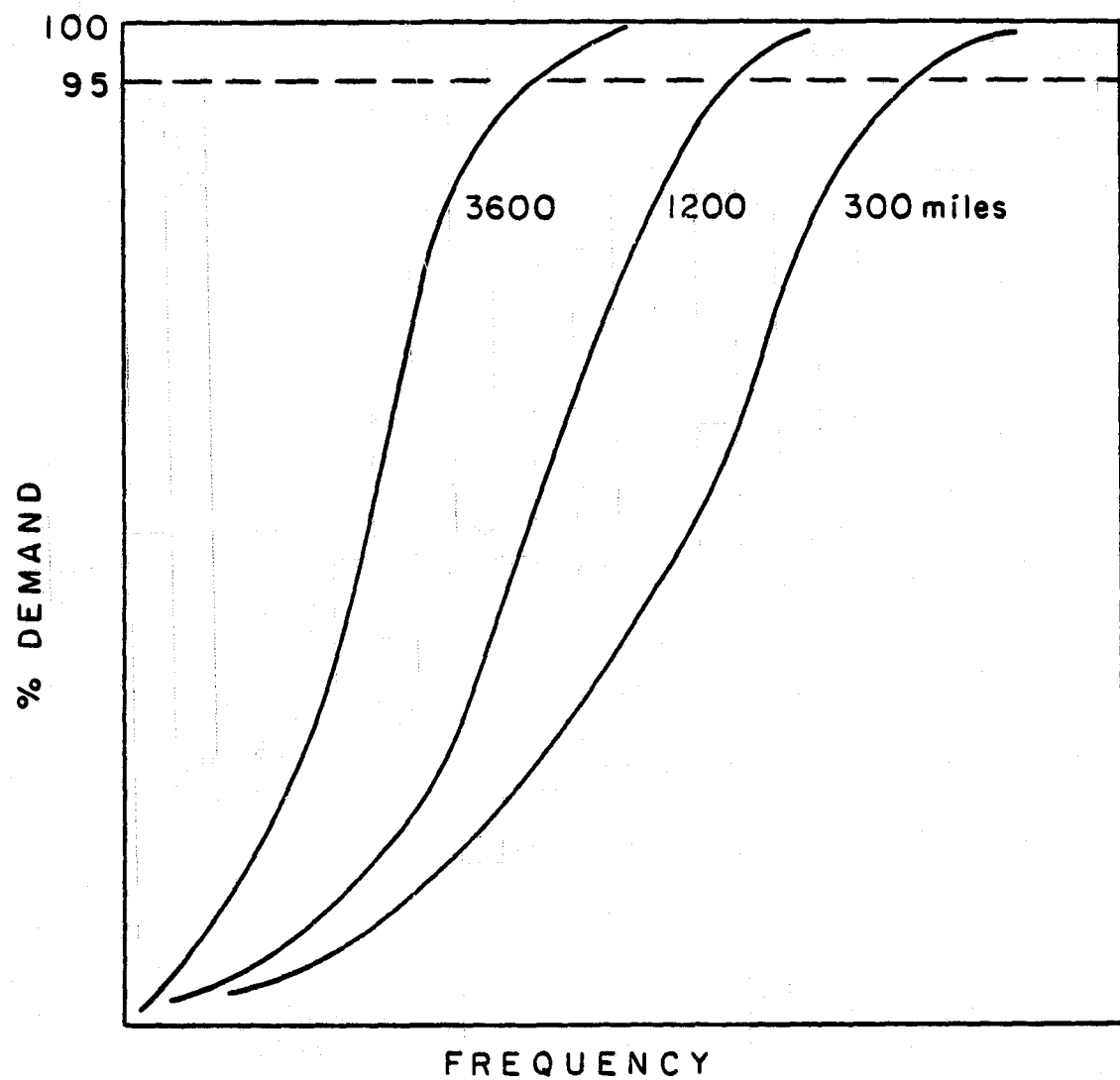


Figure 2.2 Demand Vs. Frequency

Source: R.W. Simpson, "A Theory for Domestic Airline Economics", Flight Transportation Laboratory Report R74-2, MIT, July 1974, p. 18.

that each carrier provides. It includes the differentiation of the various service classes based upon meals, first vs. coach seating configurations, movies, free stereo and so on.

The primary significance of these quality variables, when viewed from a system-wide perspective, is their impact upon the interfirm strategies among airlines. As Taneja states,

"Since the price charged is the same on all carriers in a given market, a marketer can increase his carrier's share of the market by showing his service is different. Thus from a marketing point of view service can be considered differentiated. For example, on a given route the services offered at different times of day are quite different services from a passenger's viewpoint... Even flights that depart at exactly the same time with the same equipment are different services due to the differences in cabin service, distribution channels, on-time performance service, and services on the ground -- that is the passenger's image of carrier services." 5

Consequently, airlines spend considerable amounts on advertising and promotion in an attempt to differentiate their product.

Although carriers charge the same price in the individual markets they serve, on a system-wide basis the traffic mix that a carrier serves can vary considerably. If an airline operates in markets that are predominantly business-oriented the yield (or revenue per revenue-passenger-mile) will generally be higher than in a similar market that is pleasure-oriented. Assuming the costs of the two routes are close to being equal, the carrier that has the higher yield will experience the larger profits. In recent years, charter travel has grown considerably. Not only have the charter operators, "non-skeds", diverted considerable traffic from the scheduled operators, but the certificated airlines have entered into the charter business subject to various CAB limitations. The important point, however,

is that charters' lower yields are justified by their significantly lower costs and consistently higher load factors.

One of the most pronounced characteristics of airline demand involves the fluctuation of traffic over time. Demand patterns vary (1) with the hour of the day, generally peaking around 9 a.m. and 5 p.m. depending upon the particular market and the influence of changes in time zones; (2) with day of the week due to the business cycle and the market -- this cycle is less pronounced than others; and (3) over the year as a function of the particular month. For example, August is generally a peak month and February and November are low demand periods. As stated earlier, the obvious consequence of such variations in demand is either excess capacity in February and November if fleets are expanded to meet August demand or lost traffic to competitors if fleet size is maintained at levels dictated by the February and November valleys. One way out of the dilemma, excluding complementary route awards by the CAB, is seasonal leasing or more aggressive development of markets that would utilize the excess capacity.

However, in air transportation the prices that are charged are subject to the approval of the CAB. While individual carriers may initiate fare changes, the Board has the right to disallow the change, and establish maximum and minimum fares between city pairs.

As a result of the Domestic Passenger Fare Investigation fares are based upon a distance formula in which the fact that costs decrease as distance increases is one of the primary motivations. Consequently, although fares increase with the length of the trip, they do so at a decreasing rate.

2.4 Supply and Demand Interactions

Depending upon the particular time horizon, the variable costs for an individual flight are relatively small. Once a flight has been scheduled (schedule changes usually occur monthly in response to seasonal demand fluctuations), the opportunity cost of cancelling the flight would only include the fuel and oil that would not be consumed, and the landing fees. On the basis of a slightly longer time horizon, say next quarter, the cost savings for cancelling a flight would include fuel and oil, landing fees, and direct maintenance. However, maintenance burden and ownership costs would still be paid, so that they could not be considered as part of the savings.

When considering the interactions between supply and demand, several points are particularly important. In the first place, the quantity of supplied service does not equal the quantity demanded. The number of departures (and seats) in a given market is a function not only of the demand of a single region pair but also of several other segments that might be part of a particular route or even network. In addition, given the demand-frequency responses discussed earlier, carriers almost always schedule excess capacity so that passengers are not turned away. The implication of the supply-demand disparity is the need to define the ratio of the demand for seats and the seats supplied. This ratio is referred to as the load factor and can be calculated with various units of demand (i.e., passengers, passenger-miles, tons, ton-miles) and corresponding supply units (available seats, seat-miles, available tons, ton-miles). In any case, both the

quantity demanded and the quantity supplied are variable.

A somewhat modified definition of load factor is also useful in analyzing the supply-demand interaction. Since different aircraft exhibit varying operating costs, for a given flight the cost that the airline incurs can vary considerably. Because the price that each passenger pays is independent of the aircraft that flies a given route, the larger aircraft, with higher per hour costs, will require more passengers to cover these costs. Therefore, the break-even load factor, LF_{BE} , can be defined as the ratio of the number of passengers required to generate revenues equal to the cost of a flight, divided by the available seats.

With most costs, in the short run, basically fixed, once the break-even load factor is reached the profit margin for each extra passenger is quite large. It has been estimated that 85-90% of the revenues from passengers over LF_{BE} goes directly to pretax income. It is here that the lower costs per seat mile of the widebody jets are so attractive. Although it takes many more passengers to reach the break-even point, having done so, the profit margin for each passenger above break-even is much greater on a 747 than a DC-9. The fact that larger aircraft are flown on longer stage lengths, which lowers costs per seat mile, further enhances the advantages of the widebodies (assuming break-even LF can be reached).

The existence of the high operating leverage under which airlines operate indicates the importance of matching aircraft (or plant capacity) to demand in as many markets as possible. While the economic issues discussed earlier may limit this matching process, clearly the more successfully a carrier can make the match, the better chance it will have

to reach load factors above LF_{BE} and thereby enjoy increasingly higher profit margins.

A variety of factors, most notably the interactions of network and scheduling constraints, prevent carriers from supplying service optimally in every market they serve. Nevertheless, the implication, once again, is that long haul, dense markets served with large, low-variable-cost aircraft are desirable from the point of view of generating large profit margins.

With the large fixed costs, previously discussed, and the volatility of demand, airlines compete heavily for each additional passenger. As one carrier reports, one additional passenger on each flight is worth \$23⁶ million a year.

2.5 Summary

This chapter has attempted to explain the nature and unique characteristics of air travel demand and costs. In so doing, the importance of network analysis can be seen both from the point of view of traffic flow as well as aircraft scheduling and utilization. Through its control of routes and fares (based on distance) the CAB strongly influences the level and pattern of demand available to each airline. Based upon the demand patterns of the markets they serve, and the cost characteristics of their fleets, airline managements schedule frequencies of service so as to stimulate demand and, at the same time, minimize costs.

Departures in a given city-pair, and the aircraft selected to perform

these departures are selected upon the segment demand and not just the traffic in a single city pair. If the segment flow is sufficiently large to justify larger aircraft, costs per seat can be lowered due to the economies of scale of these planes.

References

1. See Richard A. Posner, "Theories of Economic Regulation", The Bell Journal of Economics and Management Science, 5 (Spring 1974) 335-358, and George Stigler, "The Theory of Economic Regulation", The Bell Journal of Economics and Management Science, 2 (Spring 1971), 3-21.
2. See R.W. Simpson, "Advanced Airline Planning Models - A Tool for Regulatory Policy", M.I.T., Center for Transportation Studies Report 77-8, April 1977.
3. Carriers have organized to form the Mutual Aid Pact (MAP). This plan returns some of the lost profits to the struck carrier, in the form of payments from the competitors that benefit (who are members of the pact) in the form of windfall profits because of the strike.
4. Air Transport Association of America, Economics of Air Transport: An Overview, p. 4.
5. Taneja, N.K., The Commercial Airline Industry, Lexington: D.C. Heath, 1976, p. 62.
6. Trans World Airlines, Annual Report 1975, p. 1.

3. FACTORS AFFECTING PROFITABILITY

In order to model airline profitability, it is necessary to identify those control variables that are used to influence airline performance. Drawing upon the discussion of demand, costs, and their interactions in Section 2, this section discusses in greater detail those managerial and regulatory factors that are used to adjust carrier performance. By managing both assets and liabilities management can, theoretically, greatly influence profits within the environment of controlled pricing and entry and exit of the CAB.

Managers influence demand by effective marketing that successfully differentiates their service from that of the competition and defines the mix of services that best utilizes their assets.

Costs, on the other hand, are controlled by efficient use and selection of equipment and personnel. With fares basically fixed, adjustment of schedules and aircraft type ultimately results in changes in a carrier's break-even load factor. By comparing this load factor with the load factor that is actually obtained (due to the demand carried by a particular airline), one can fairly easily determine the profitability of a carrier.

Although the bulk of this section is devoted to a discussion of the various factors that are considered influential in their impact on airline profitability, the initial portion will cover the general modeling philosophy that was followed and some of the previous financial models that have investigated corporate decision-making.

3.1 Econometric Models of the Firm

Mathematical models of corporate processes are designed to measure and analyze relationships among variables that represent various economic, operational, and in the case of airlines, regulatory factors that exist in the market structure in which these firms operate.

A variety of models have been constructed in order to explain very specific aspects of corporate performance. The range of topics covered by these formulations not only indicates the potential uses for such tools, but also emphasizes the need for the model builder to carefully identify the purpose of a proposed model, and the level of detail necessary to satisfy its objectives. Models can be predictive, descriptive, or normative, again depending upon the objectives of the model builder. They can consist of multi-equation simulation formulations that are based upon standard econometric techniques or they can consist of accounting identities.

Within the framework of simultaneous multi-equation models, several examples exist that further illustrate the range of application for this type of statistical tool. Davis, Eaccappolo and Chaudry have developed an econometric model to be used for corporate planning analysis in AT&T by quantifying the economic interrelationships of demand, production, and finance.¹ They conclude that the present state of applied economics and the availability of planning technology is such that firm behavior can be analyzed by applying standard economic theory. While relating a corporate submodel to a model of the national economy and a model of management control policies, the core of the formulation is the corporate submodel that consists

of mathematical relationships for price, demand, revenues, production, finance (expenses), and capital market relationships (cost of capital).

A second example of an econometric representation of a firm is provided by Saltzman's² analysis of an unidentified company in which the model is organized into three sectors: (1) sales, prices, and inventory and output, (2) investment and expenses, and (3) costs and profits. These three sectors were represented by 10 equations and several identities with the coefficients being estimated via ordinary and two-stage least squares procedures. Saltzman's purpose in building the model was to develop a relatively comprehensive simultaneous equation model of a firm. The model, then, is more descriptive than predictive, although it could theoretically be used for the latter.

A third study³ undertaken by J.W. Elliott was designed to forecast sales and other performance elements in a firm's income statement. Utilizing eleven structural equations the model was designed to simultaneously explain the lines in a corporate income statement. The primary hypothesis under which the model was formulated was that many aspects of corporate performance are jointly determined and can only be explained in a simultaneous, multiple-equation model that deals with the aspects of interrelated relationships. Elliott concludes

"Simultaneous equations models of corporate financial performance of the type developed and evaluated in this study can provide an important means for explaining this performance and a potentially useful means for predicting performance." ⁴

In addition to the simultaneous equation econometric models discussed above, it is also possible to construct a financial simulation model that

is made up of accounting identities taken from the balance sheet and income statement. Warren and Shelton⁵ in constructing such a model submit that such a formulation can assist corporate managers with a means of specifying why and when the firm needs financing and the risks and rewards possible to those who can provide the funds. Utilizing Sears Roebuck as an example, Warren and Shelton feel that a financial simulation can allow for the quantification of the effects of alternative policies and decisions such as debt/equity ratio, dividend yield, price earning ratios, and others.

Perhaps the common factor in all the models discussed thus far is the use of a simultaneous equations formulation. While such complexity is clearly necessary if one of the objectives of the model is to capture the structural relationships within and around a firm, however, if the goal of the model is purely predictive, a reduced-form⁶ system can be employed. The strength of the equation then is measured on how well the relevant predictions are made. Such a framework can also free the model from the requirement that the underlying corporate relationships be accurately represented. Although this is not to say that intuitive or empirical hypotheses should be ignored, as such beliefs can provide the basis for the initial selection of explanatory variables. Fromm and Hyman⁷ have developed single-equation, reduced form models that are used to predict sales as a function of various macroeconomic variables such as personal consumption expenditures and changes in non-farm business inventories.

Generally speaking, the single-equation, reduced form format was the procedure that was initially followed in the development of the airline profitability model. Having determined that the primary purpose of the

model is to provide predictions of profitability, or cash flows, the need for a detailed structural, descriptive model was considerably reduced. At the same time, a major consideration of the specification process was to account for the basic variables that are suggested by the economic and regulatory framework discussed in Section 2.

An example of a single-equation, econometric model that evaluates airline profitability was developed by Fruhan.⁸ In short, Fruhan found that the variables controlled by the CAB are more influential than those under managerial direction: "The CAB exercises greater control over the relative profitability of the carriers than do the carrier management groups themselves."⁹

Not only does Fruhan's study reinforce one's intuitive belief that the CAB exercises considerable control over carrier performance, but it also provides an excellent discussion of many of the factors that are considered important in the determination of carrier performance. These factors will be discussed shortly.

Having determined the purpose of the model, to predict profitability, or cash flows, and that a detailed, simultaneous equation is not necessary; the next step is to identify the operational, financial, and regulatory variables that are likely to cause variation in the response term. Having done this, the next step is to determine if the factors that have been identified can be quantified.

Figure 3.1, taken from Roy J. Pearson's discussion of airline efficiency, gives a pictorial representation of the forces and relationships that determine performance. While most analyses have focused on the lower

box (operational, network, and economic characteristics), it is, in fact, the interrelationship of all these forces that determine carrier performance; for example, Delta Airline's ability to remain highly profitable despite what some would argue are poor network and operational constraints. In any event, to formalize the hypotheses that are implicit in Figure 3.1 requires consideration, at least, of specific variables that are representative of each of the boxes that are shown. The remainder of this chapter will expand on each of the factors and discuss variables that have been or could be used to represent a given area.

3.2 Model Specification Dependent Variable (Profit Performance)

Selection of an appropriate measure of a firm's financial performance rests upon individual assumptions concerning firm behavior. While several newer theories are based upon the belief that firms attempt to maximize something other than profits,¹⁰ it is not unreasonable to assume that on a long run, total firm basis, the objective of management is still to maximize the return on the capital invested in the company by the owners of the company's stock. Even if managers do not seek to only maximize shareholder wealth, such a goal is bound to be of considerable importance. It is reasonable to assume, therefore, that airline managements will be directing their decision-making and relationship with the CAB in the direction that maximizes return on invested capital.

In addition, several other measures of profitability are often

considered as appropriate indicators of firm performance and should, therefore, be mentioned and viewed more closely before they are discarded entirely. These include:

Profit Margin = Net Income/Sales

Return on Total Assets = Net Income^{*}/Total Assets

Return on Equity = Net Income/Shareholder's Equity

Expansion of the hypothesis that maximization of market value is management's objective can be made by assuming that the value of the firm is the current market value of all outstanding claims on the firm's future and present cash flows. So that maximizing future cash flows will, in turn, maximize the wealth of the owners. Since capital budgeting decisions are made on the basis of an investments impact on firm value, via the present value of the project estimated cash flows, total firm cash flows represent not only a measure of firm value, but also a variable that can be useful in estimating future capital budgeting decisions. Consequently, using cash flows as a dependent variable also seems reasonable.**

Turning to various choices of independent variables (or carriers), several possibilities are suggested by the remarks in Section 2 as well as by the model of Fruhan mentioned earlier. In order to maintain some logical pattern of discussion, factors will be discussed in the context of those areas depicted in Figure 3.1. As is illustrated by the figure, one of the complications that must be faced when dealing with air transportation is the interrelationships among many of the factors, plus the need to

* Before interest expense and taxes.

** Cash Flow = Transport Revenues - Operating Expenses

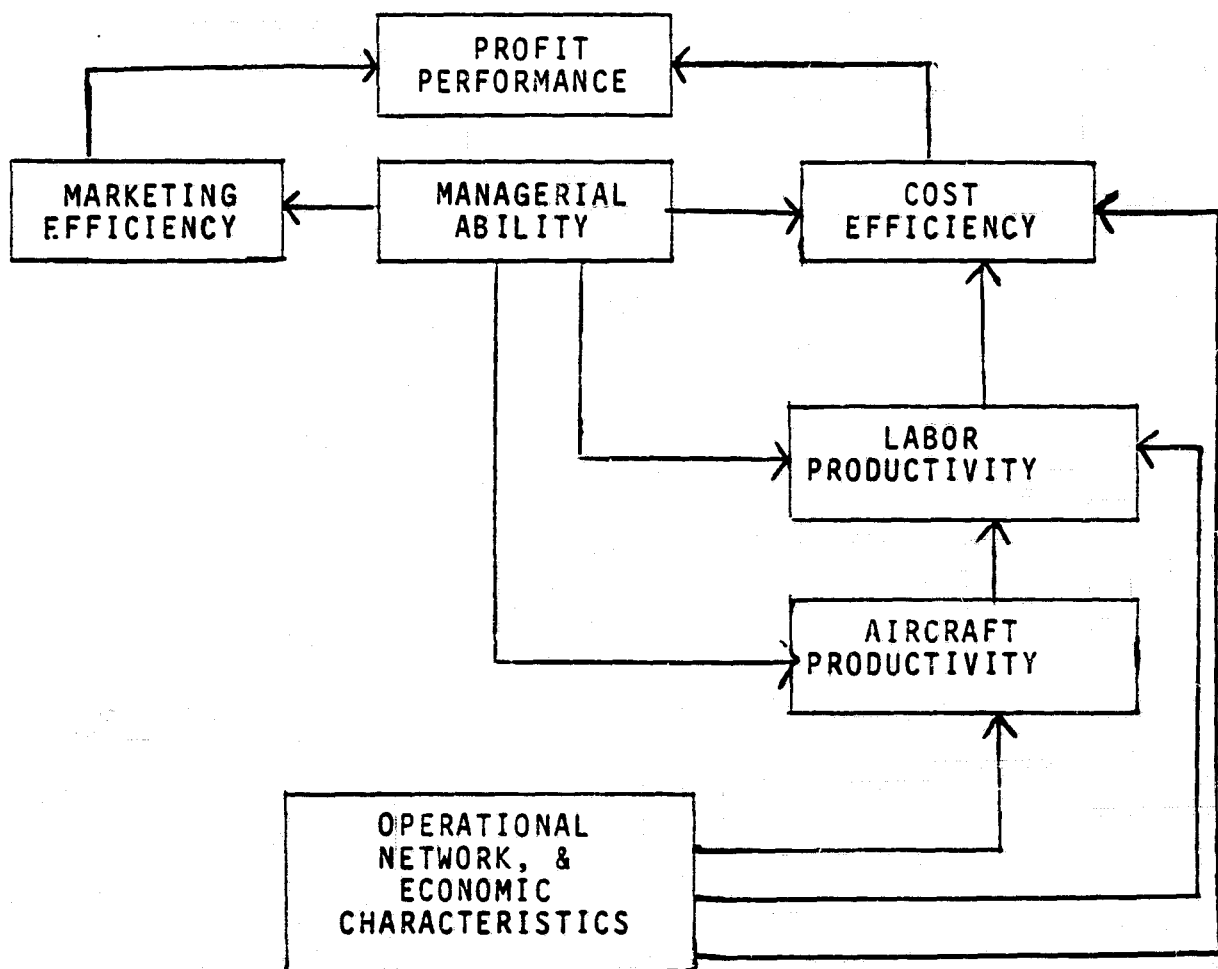


FIGURE 3.1 Factors Affecting Profitability

Source: R.J. Pearson, Airline Efficiency, Transport Studies Group Polytechnic of Central London, 1976.

aggregate the characteristics of many nonhomogeneous markets (long haul vs. short haul, business vs. pleasure, dense vs. low density) into a single measure. This requirement necessitates not only some flexibility but also limits the use of some factors that have high intuitive appeal with respect to their impact on profitability.

Nevertheless, proper definition of the conditions and circumstances that impact upon a firm's revenues and/or costs should enable a model to be constructed that explains a carrier's performance on a system-wide basis.

3.3 Operational, Network and Economic Characteristics

Perhaps the first point that comes to mind regarding this aspect of profitability measurement is the pervasive control by the Civil Aeronautics Board (CAB or the Board) in the regulation of pricing, entry and exit by participating firms. While some operational variables are controlled by management, the CAB has, in effect, taken many decisions out of the hands of management and substituted regulation for traditional market forces. The theory as to why such regulation is necessary will not be covered here nor will the arguments pro and con for the elimination of regulation.¹¹

By controlling entry and exit to and from various city pair markets, the CAB effectively controls the basic level of traffic demand each carrier can address. In turn, the number of competitors that can participate in any given market is also controlled by the Board. This leads to the definition of several factors that one would intuitively expect to impact on profit performance.

3.3.1 Competition

The precise effect of added competition on the profitability of an individual firm depends upon the assumptions that are made concerning the oligopolistic behavior within the market being studied. Ranging from an assumption that competitors will maintain fixed output regardless of production decisions by any single firm (Cournot) to the belief that firms will schedule (or price) collusively, decisions concerning certification of new carriers in a market can have varied results.¹² In addition to requiring assumptions relative to the competitive reactions of various firms, additional assumptions are required concerning the specific nature of demand in the market, to see if it is business (inelastic price elasticity of demand) or pleasure (elastic price elasticity).

In general, however, the addition of carriers into a given market has generally resulted in a reduced market share and, therefore, lowered the profitability of the incumbent airline.

Monopoly markets (defined be those where one airline has a market share greater than 80%) generally allow for fewer flights and higher load factors than would exist under more competitive situations.

Before too quickly assuming that competition, or a lack thereof, can immediately lead to profitable operations, it is necessary to consider two additional variables.

3.3.2 Stage Length

As was discussed in Section 2, break-even load factor, for a given aircraft or for an entire system, decreases as stage length increases. Since CAB fare calculations are based upon distance, longer stage lengths increase revenues, although at a decreasing rate.

$$\text{i.e. } \frac{\delta R}{\delta X} > 0 \qquad \frac{\delta^2 R}{\delta X^2} < 0$$

R = revenues

X = distance

Also, at longer stage lengths, costs per seat-mile or ton-mile are considerably less, since the expenses (per seat-mile) associated with putting capacity in the air (crew wages, fuel, maintenance, depreciation) are significantly reduced.

A carrier that produces 100 revenue passenger-miles consisting of one passenger flying 100 miles will incur lower costs than a carrier that carries one passenger 50 miles and a second passenger 50 miles. While the output is the same, the ticketing, boarding, and unloading costs are, in effect, doubled and the carrier with shorter stage lengths suffers accordingly.

3.3.3 Density

Increased demand, or density, not only provides access to potentially increased revenues but allows for more efficient utilization of aircraft. Carriers operating in dense markets can, potentially, more easily attain (or

exceed) break-even load factors (for a given stage length) on a larger number of flights. Carriers that, because of CAB regulation, are required to serve various routes with a level of service not justified by the traffic density are forced to provide costly service that is not covered by the revenues they receive.

An important additional factor that is not explicitly defined in any of the three variables discussed thus far is the significance of the interrelationship among these three factors. As Fruhan states:

- "One might predict that a monopoly operation in a city pair market would be quite profitable. Such a prediction would probably be in error if the total trip length in the city pair market was less than 300 miles. The prediction would probably also be in error if the trip length were 2500 miles, if only five passengers per day made such a trip." 13

For the moment, suffice it to say that these interrelationships should be kept in mind when factors are quantified for use in a model.

3.3.4 Concentration

Aggregation of traffic demand in a small number of markets should allow for concentration of aircraft in these markets and thereby result in a larger market share and increased profitability. Aircraft are more readily available to be scheduled to accommodate peak demand periods, support and maintenance facilities can be centrally located, backhaul problems can be reduced, and aircraft can be "repositioned" over dense routes rather than over lightly-traveled markets. In those less dense, isolated markets where service is required, small aircraft can be operated infrequently, thereby keeping costs down.

3.3.5 Seasonality

The nature of an airline's seasonal demand and the inability to maintain inventories to compensate for peak demand was covered earlier. In short, once again, seasonality results in either underutilized capacity during slack periods if fleets are expanded to meet peak demand; or lost traffic if capacity is maintained so as to efficiently satisfy demand during slack periods. With high operational leverage, unused capacity is a burden that a profit-maximizing firm cannot afford.

The factors discussed thus far, in general, are affected by virtue of the CAB's control of entry and exit by carriers in a given city (or region) pair market. With the exception of the level of competition that can be altered by managerial decisions concerning scheduling, aircraft choice, and in-flight amenities, the number of competitors per route, the mix of long and short haul routes, and the ability to draw from dense or spare routes is regulated by the CAB. However, as Pearson states,

"Any effects that the characteristics in the bottom box (operational, network, and economic characteristics) may have on profit performance are felt indirectly via their combined effects on costs and marketing results." 14

3.3.6 Yield

Since all certificated airlines are required to charge the same price for identical service, a more accurate measure of the revenue generating strength of a carrier's system is the amount of revenue received per unit of output. While an increase in this measure could possibly improve

profitability, the impact of yield (price) on the demand for travel applicable to a particular airline depends upon the segmentation of demand (business, pleasure, first class, coach, cargo, etc.) and the price elasticities of these groups. Assuming a relatively inelastic demand curve,¹⁵ an increase in yield should increase airline revenues. Again, certain managerial decisions are available even with CAB-regulated fares; managements are free to choose which market segment to aim for (business, pleasure, cargo, charter) and can, therefore, affect their yield. Nevertheless, the CAB establishes the framework in which the corporate manipulations are made.

With the caveat of Pearson, mentioned earlier, strictly in mind, we shall move on to factors that are more directly under the control of corporate management.

3.4 Aircraft Productivity

Perhaps the single most important capital budgeting decision made by an airline is the choice of aircraft type and the number to purchase. Not only does this decision represent investment in assets valued from \$5-\$45 million but, in aggregate, it also involves 50-60% of the total value of the firm's assets.

At a somewhat simplified level, aircraft are purchased to match design characteristics with the operational and economic factors discussed earlier.¹⁶ As technology has made aircraft more productive via increased

speed, or more seats, these factors, combined with greater fuel efficiency, efficiency due to better engines and more efficient air foils, have allowed unit costs to decline until recently, when fuel and labor costs have skyrocketed. Thus, carriers that can employ more efficient, more productive aircraft not only realize the benefits of lower unit costs, but also are able to convey product differentiation (wide-body vs. narrow-body, jet vs. prop) and more reliable, dependable equipment.¹⁷

At the same time, newly introduced aircraft are not without their problems, as they often require certain "break-in" periods during which time costs have been higher due to mechanical difficulties as well as unfamiliarity on the part of pilots, mechanics, and ground handlers.¹⁸

3.4.1 Utilization

As a common indicator of aircraft productivity, utilization measures each carrier's ability to match its capacity with the demand in the markets it serves. In addition, however, it is also a reflection of the regulatory process in that longer stage lengths (from CAB route awards) allow for greater aircraft utilization. Assuming that utilization is also a function of demand, carriers with seasonal networks are likely to have underutilized capacity. A carrier with short stage lengths will, because of increased ground handling time, taxiing, and so on, have its aircraft utilization reduced, thereby requiring additional capacity to satisfy demand.

Needless to say, it is imperative that sufficient demand exist to justify the utilization rate that is achieved. Flying empty aircraft in order to maintain utilization rates is far more costly than allowing aircraft to sit on the ground. The latter, however, reflects serious disparities between anticipated and actual demand, or severe seasonality. Either case represents large fixed costs in the form of interest and depreciation expenses that are not matched by any form of revenue.

Utilization, while clearly a function of stage length, reflects management's ability to match supply and expected demand and at the same time deal with the seasonality issues discussed earlier.

3.5 Labor Productivity

Closely related to aircraft productivity is the productive capacity of the carrier's labor force. The greater the productivity of the fleet, the more productive the labor force. As has been mentioned previously, longer stage lengths not only allow for greater aircraft utilization, but also spread the labor costs, which are basically fixed, over a larger ton-mile base.

The importance of employee productivity was clearly demonstrated in a recent study of Delta and Eastern Airlines.

"Bearing in mind the similarity of routes, it is fair to conclude that Eastern is 13-20% overstaffed by Delta standards....Eastern should be able to service its system with some 29496 employees or 5829 fewer than it has. A reduction of 5829 employees at Eastern's average salary would save some \$84 million." 19

And lastly, if a large proportion of output is produced in non-scheduled service, labor costs can be significantly reduced, as this type of service allows for certain economies of scale in the provision of ground handling and inflight services. (Of course charter service also provides lower yields.)

Labor efficiency can also be greatly affected by the relationship that exists between the management and the various labor groups. Table 3.1 shows the unions that are presently representing various categories of workers at individual carriers. Table 3.2 shows some of the strikes that have occurred at selected carriers since 1957. As mentioned in Section 2, work stoppage can severely affect an airline, and while the carriers have responded to strike threats by forming a mutual aid agreement, the absence of strikes and the ability to avoid mutual aid payments are certainly advantageous. Of all the trunks, Delta Airlines stands out as having the best labor relations and labor productivity reflected in the absence of unions and strikes.²⁰

Ultimately, both labor and aircraft productivity and the airline's operational and economic characteristics manifest themselves in the cost function that each airline faces. It is at this point, as well, that the entrepreneurial skill of individual managers is felt.

TABLE 3.1 UNION REPRESENTATION OF AIRLINE EMPLOYEES

Airline	Pilots	Flight Attendants	Mechanics	Dispatchers	Flight Engineers
American	APA	TWU	TWU	TWU	FEIA
Braniff	ALPA	ALPA	IAM	ATDA	
Continental	ALPA	ALPA**	IAM	TWU	ALPA
Delta	ALPA			PAFCA	
Eastern	ALPA	TWU	IAM	IAM	ALPA
National	ALPA	TWU*	IAM	TWU	FEIA
Northwest	ALPA	IBT*	IAM	ALDA	IAM
Pan American	ALPA	TWU	TWU	TWU	FEIA
Trans World	ALPA	TWU**	IAM	TWU	ALPA
United	ALPA	ALPA**	IAM**	IAM	ALPA
Western	ALPA	ALPA	IBT	TWU	ALPA

* Change in representation (last two years)

** Representation activity

TABLE 3.2 DOMESTIC TRUNKS STRIKES, 1957-1975

BN.....September 21 - 22, 1974

EA.....July 8, 1966 - August 19, 1966

NA.....September 18 - October 24, 1957

January 31 - May 26, 1970

July 15 - October 31, 1974

September 1 - December 31, 1975

NW.....July 7 - 23, 1960

October 11 - December 31, 1960

January 1 - February 24, 1961

July 8 - August 19, 1966

June 30 - October 11, 1972

TWJuly 8 - August 19, 1966

October 20 - 21, 1970

November 14 - December 18, 1973

3.6 Cost Efficiency

Since a fairly lengthy discussion of costs was given earlier, only a few additional points will be made at this time.

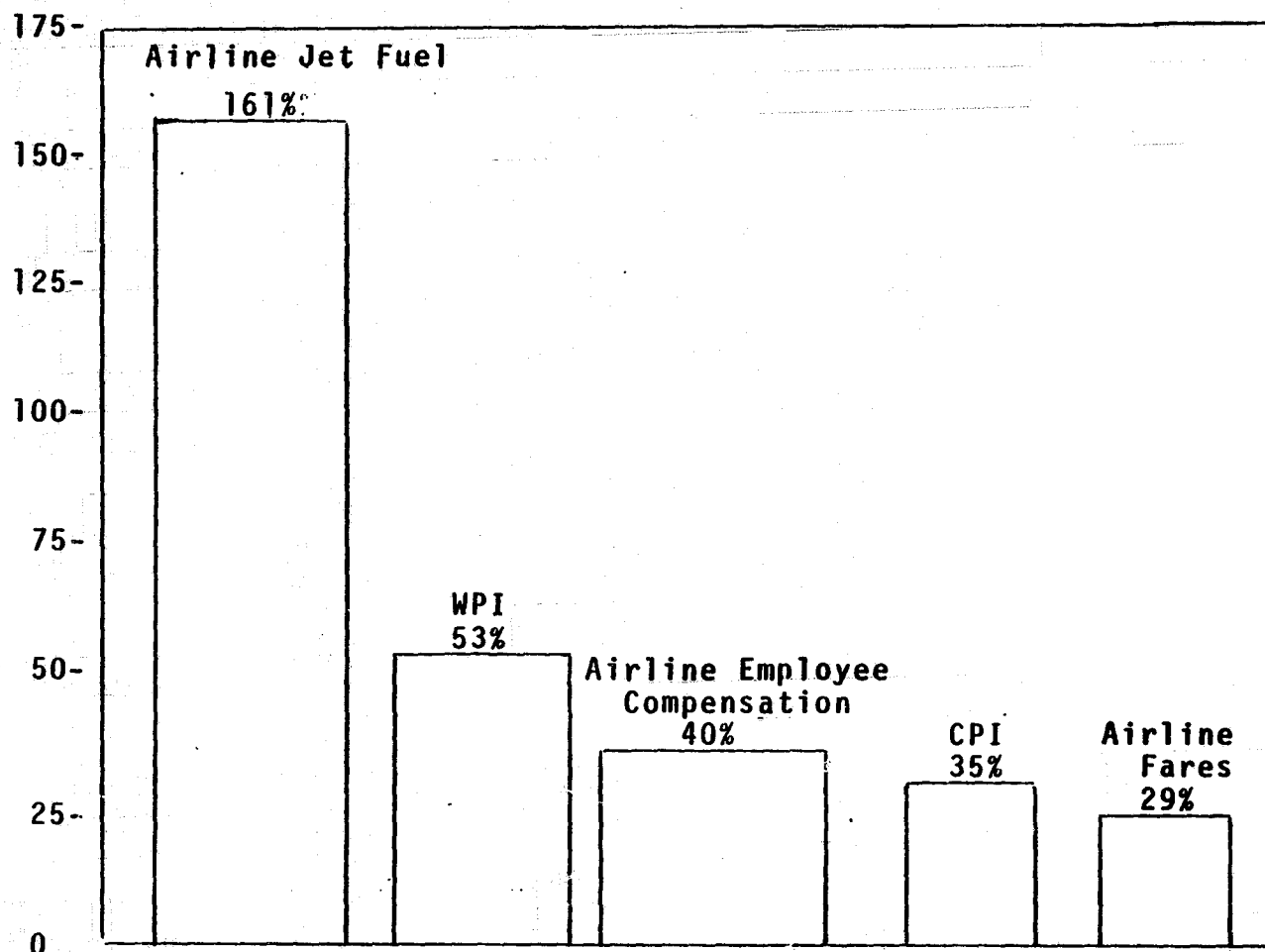
Pearson, again, argues that 30% of airline costs lie outside management's direct control (e.g., fuel and landing fees), while the remaining 70% are open to executive constraints and evaluation.²¹

Disaggregating in a slightly different fashion, 30-40% of total operating costs are incurred on the ground in conjunction with servicing aircraft.²² Of the remaining 60%, three components have dramatically impacted on the cost of providing service and have significantly eroded the initial gains that increased aircraft productivity provided.

3.6.1 Labor Costs

Several factors have contributed to the increase in employee compensation and the high wages paid airline employees (see Figure 3.2). At the risk of some oversimplification, airline employees are generally in highly qualified, technical professions that require considerable training periods (pilots, mechanics, and, to a lesser degree, flight attendants). Given the impact of work stoppages that has been previously mentioned, wages are pushed upward by the demand that exists for a somewhat fixed supply of assets. Although new pilots and mechanics can be trained, in the short run they can exert significant leverage. Secondly, as a highly unionized industry, the ability to present a more unified and powerful position on the

FIGURE 3.2 Cost Increases Versus Airline Fares
2nd Quarter 1976 Compared to 1972



* Average revenue per passenger mile.

part of individual occupations has contributed to the fact that employee compensation in the airline industry now averages \$20,000 per year and is the highest of all major U.S. industries. Table 3.3 gives some illustrative wage rates.

3.6.2 Fuel Costs

The impact of the rising cost of fuel has manifested itself in several areas of carrier operations. First, as the average price of fuel has risen 160 percent, from 12 cents per gallon in 1973 to 32 cents per gallon in 1975, the portion of direct operating costs that this represents has increased to around 35-40 percent (see Figure 3.3). This has resulted in numerous requests (and approval) for fare increases. In addition, operating procedures (i.e., cruise speed, taxiing with engines shut down) and schedules have been modified to reduce fuel consumption. And lastly, higher fuel prices will accelerate the retirement of less efficient aircraft, particularly in light of recent governmental directives concerning noise and exhaust emissions. This, of course, harkens back to the remarks in the Introduction stating that some \$60 billion will be required for fleet modernization and expansion. Where the funds will come from for these aircraft brings us to the last major cost element.

TABLE 3.3 ILLUSTRATED PAY LEVELS (WAGES ONLY)

	July 1976			
	Low	High	Life of Contract High	
B-747 Captain	\$69,400 (TW)	\$77,500 (AA)	\$82,300 (EA)	1977
B-727 Captain	\$49,500 (TW)	\$57,600 (AA)	\$59,600 (TW)	1977
Flight Attendant	\$11,000 (TI)	\$13,000 (AA)	\$15,300 (AA)	1977
Mechanic	\$17,300 (TI)	\$19,000 (UA)	\$23,000 (NC)	1978
Station Agent	\$14,400 (BI)	\$15,300 (NW)	\$18,200 (NW)	1979

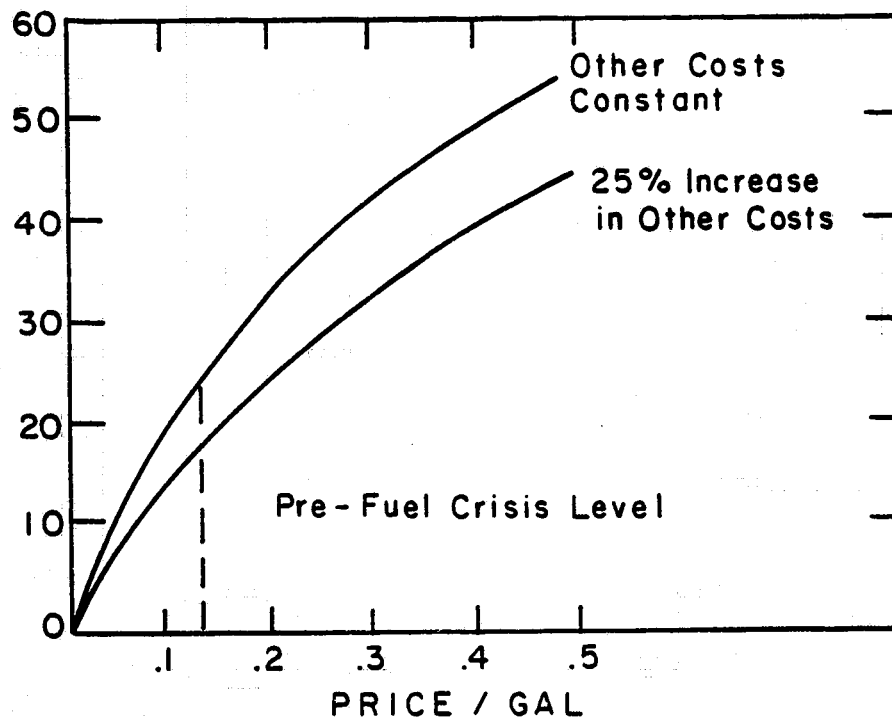


Figure 3.3 Fuel Costs as percent of DOC

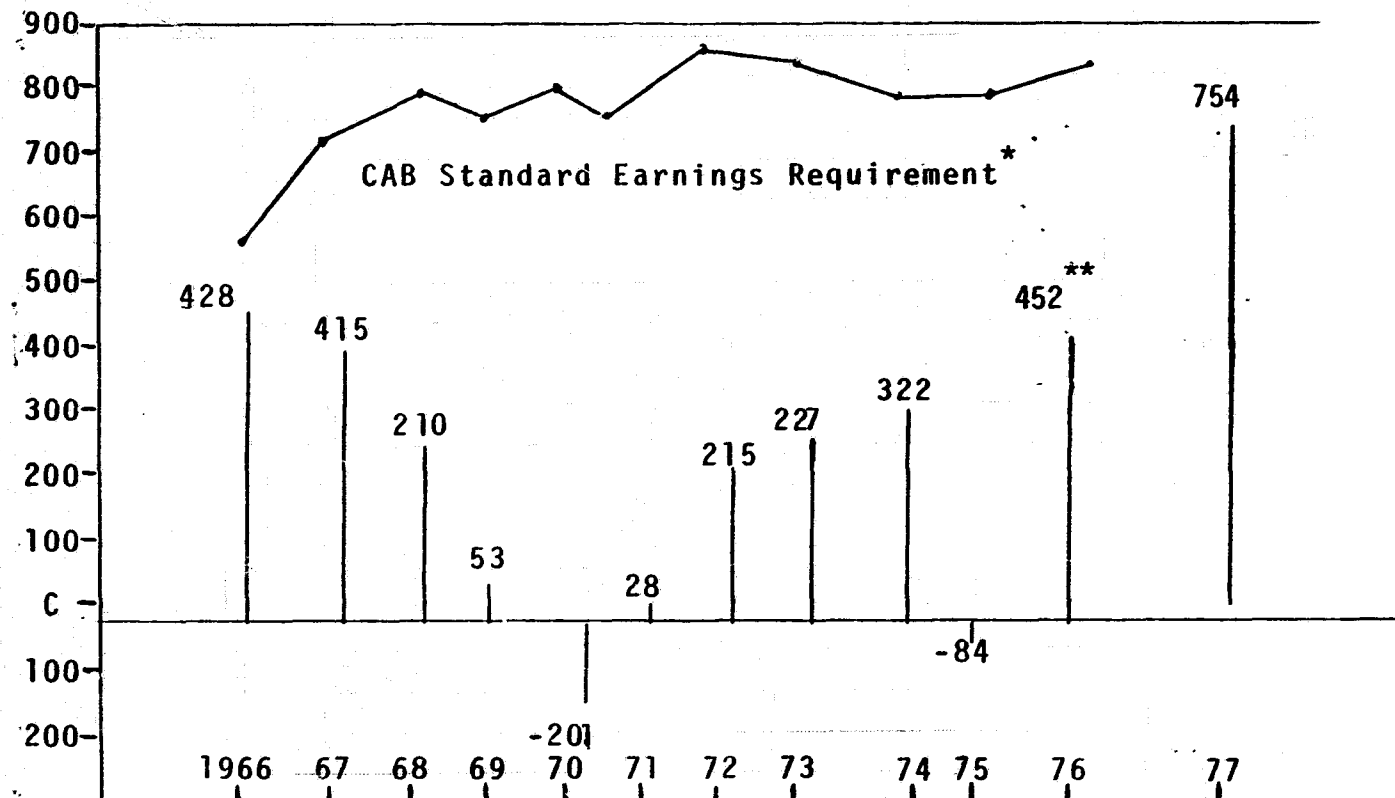
Source: Gordon Sim and Russell H. Hopps, "Commercial Transports - Decade of Derivatives", *Astronautics & Aeronautics*, February 1975, p. 31.

3.6.3 Financial Costs

As a highly capital-intensive industry, carriers have required huge amounts of funds to finance fleets that have not only expanded but become increasingly more expensive. Since internally-generated funds have not been (and will not be in the future) sufficient to provide the capital requirements of the airlines, external sources have been extensively used to finance aircraft purchases. However, highly volatile earnings (Figure 3.4) have caused stock prices to fluctuate considerably and necessitated the use of high volumes of debt capital. In turn, the high financial leverage has created even more volatile equity returns. While airline industry stock prices generally move together, differences in historical and expected carrier earnings, plus varying degrees of leverage, result in variations in individual carrier's equity values. Investors' evaluation of each company's cash flow, growth opportunities, and riskiness of these flows are reflected in the market value of a share of common stock. This price, or market value per share, is set so that investors receive a rate of return commensurate with the risk of the investment. Since the expected cash flows vary from carrier to carrier, and growth estimates for each airline are different, the risk associated with each carrier varies and in turn prices cover a wide range. By comparing market values to book values of common stock, it is possible to get a quick estimate of the expected productivity of a firm's assets (see Table 3.4). Since, in recent years, market values have been less than book values, carriers have turned to heavy use of debt

FIGURE 3.4
\$ Millions

Earnings, U.S. Scheduled Airlines, 1966-67



* Equivalent to 12% return on investment and in 1976 a 5.2% profit margin.

** Excludes

Source: CAB Form 41's

TABLE 3.4 FINANCIAL DATA

	Book Value (BV)		Market Value (MV)		MV/BV		Debt/Assets	
	Per Share		Per Share (Avg)					
	1968	1975	1968	1975	1968	1975	1968	1975
AA	18.78	18.05	30.13	7.63	1.6	.42	.48	.28
BN	4.11	8.37	20.5	7.13	4.99	.85	.55	.42
CO	7.81	13.04	14.5	5.25	1.86	.40	.59	.52
DL	11.17	26.07	30.63	33.38	2.74	1.28	.33	.28
EA	17.67	14.11	37	9.38	2.09	.66	.61	.47
NA	14.91	25.93	34.5	11.88	2.31	.46	.28	.34
NW	18.09	28.87	40.38	17.38	2.23	.60	.25	.20
TW	28.64	17.57	42.63	8.88	1.49	.50	.63	.51
UA	30.66	29.29	50	21	1.63	.72	.46	.26
WA	7.26	10.33	11.38	7.69	1.57	.74	.52	.25
Industry Composite		46.73		31.27		.67	.57	.38

financing. At present, even debt financing has become more difficult as the cost of debt has risen due to increased leverage and volatile, risky earnings. Table 3.4 shows the ratio of debt to total assets for each carrier. The high values for 1968 reflect the large debt commitments resulting from the transition to all-jet fleets by the trunk airlines. Although debt levels (as a % of assets) have declined, increased risk and other uncertainties make this form of capital generation highly expensive.

An indication of the increased cost of debt financing and a measure of how close a firm is coming to financial embarrassment is given by the times-interest earned ratio. These figures are given in Table 3.5.

The reduced availability of debt capital, plus its increased cost, has resulted in the growth of leased aircraft and hybrid securities such as convertible debentures, warrants, preferred stock and others.

3.7 Marketing Efficiency

In an industry that produces largely a homogeneous product, the ability of one firm to differentiate its service from that of its competitors can provide a significant advantage. A variety of campaigns have been conducted by airlines in an attempt to create the belief on the part of consumers that their service is superior to that of the competition.

Since an airline would be hard-pressed to attract passengers if it charged a higher price than its competitors for the same service, air carrier marketing strategies have historically stressed areas of high consumer

TABLE 3.5 INTEREST COVERAGE

	1968	1975
AA	2.1	0
BN	2.0	2.6
CO	1.4	1.0
DL	9.8	5.1
EA	.27	0
NA	17.6	.68
NW	24.8	2.7
TW	1.26	0
UA	2.7	0
WA	3.0	1.37

Interest coverage = operating profit ÷ interest expense

appeal: namely, reduced flight times; increased frequencies; larger, faster aircraft; and inflight amenities.²³

While pricing flexibility does exist in the form of night coach, excursion, see-America, economy and super-saver fares among others, once such a price is set by one airline it is almost always matched by the competition. Reduced fares (they seldom seem to go up as a competitive measure) are aimed at traffic stimulation more than diversion and differentiation from the competition.

Of the management-controlled variables that constitute the so-called "marketing-mix" (product, place, promotion, price), the majority of the airline's efforts have been directed in the areas of product quality (frequencies, flight time, ground and inflight services) and promotional activities (advertising, promotions, travel agents).

Critics of airline advertising submit that airline advertising tries too hard to differentiate that which cannot be differentiated. They caution that much of this activity promotes an impression of luxurious service and exquisite cuisine that does not exist.²⁴ Instead, management should concentrate on advertising and promotion that highlights service features important to passengers and that are hard to imitate.²⁵

3.8 Management Quality

Although everyone agrees that firm performance can be altered by

- 1) increasing yields
- 2) decreasing costs
- 3) increasing load factors

they also concede that intrinsic managerial ability and effectiveness are influential in ultimate performance. The difficulty arises when one attempts to quantify something as illusive as entrepreneurial skill.

Some attempts have been made to measure managerial effectiveness by relating the total number of officers (VP's) and management to either total employees or an indicator of output (such as ATM's or departures).²⁶

While there is probably some strength in the hypothesis that a top-heavy bureaucracy at an airline is indicative of inefficiency, it is not easily confirmed statistically. Again the often-compared Delta vs. Eastern duo²⁷ makes a specific point of this issue and recent trends at Eastern eliminating much top-heavy management would tend to lend support to the theory.²⁸

The last major factor that bears mentioning is the close relationship that exists between the performance of the airline industry and the strength of the national economy. During periods of economic downturn or recession, people tend to postpone travel; businesses cut back on company trips, the number of people sent on trips, and often change from first-class to coach travel. These factors combine to reduce yields, and at a time when

inflationary pressures are causing costs to rise rapidly, profit margins all but disappear.

Given the lag between delivery and ordering of aircraft plus somewhat inaccurate forecasts of traffic growth, carriers generally order additional capacity during periods of high growth in traffic demand. Unfortunately, these factors then contribute to the existence of excess capacity and high fixed costs with extremely reduced revenue when demand declines during economic recessions. In brief, this phenomenon of macroeconomic fluctuations represents the ultimate in seasonality variations for the air carriers. In this case, however, individual airlines are far less able to adjust output or otherwise modify operations to deal with the reduced demand.

3.9 Summary

In order to specify a model that is to predict profitability, one must first identify those factors that intuitively should impact on an airline's efforts to maximize profits. On the assumption that management attempts to increase demand and reduce costs within the constraints of CAB regulation, this section has identified variables that are appealing and amenable to quantification.

As the ultimate goal is the calibration of a model that predicts profitability, a brief discussion of other corporate models is also included.

In the next section, the factors that have been listed here will be quantified and tested, via econometrics, to determine if the qualitative hypothesis concerning their impact on profitability is verified statistically.

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15. CAB-DPFI Phase 7 produced a figure for price elasticity of demand of -0.7.
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27. See McIntosh, op. cit., p. 25.
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4. AIRLINE PROFITABILITY -- EMPIRICAL RESULTS

Having identified various factors that intuitively should have a relationship to firm profitability, or cash flows, it next becomes necessary to match one's intuition with the data that is available. Generally, this requires numerous tradeoffs between what is considered an ideal quantification, available information (either by firm or time frame) and ease of collection. In addition, use of regression analysis requires certain assumptions concerning the data being analyzed, the model that is specified, and the error terms that result when the model is calibrated.

In all the model specifications that will be discussed, a linear additive form was used such that the models were linear in the coefficients. Various nonlinear transformations were also tested of individual carriers (independent variables), implying that the relationship between the response variable and the particular carrier is non-linear, whereas the coefficient is not.

In addition, use of a linear, additive model implies that the elasticity of the dependent variable with respect to a particular independent variable is not constant over the range of observations. As a first effort, such an assumption seemed reasonable. The log-linear model indicates constant elasticities, and can only be used when all the values of both dependent and explanatory variables are positive; this led to a change of definition of cash flow to include depreciation, such that all dependent variables were positive for individual carriers.

In selecting variables with which to specify the models to be

tested, the major thrust of the effort was to determine a quantifiable measure that had as its foundation the factors discussed in Section 3. As the modeling process proceeded, those variables that produced satisfactory results were retained, while those with poor statistical strength were, at least temporarily, removed from the model. When new variables were added, their selection was once again based upon their ability to relate to the factors of Section 3.

For the most part CAB documents have been used to provide the necessary data. Specific documents used have included the following:

AIR CARRIER FINANCIAL STATISTICS

Passenger revenues

Transport revenues

Maintenance expense

Promotion and sales expense

General and administrative expense

Depreciation

Total operating expense

Operating profit

Interest expense

Net income after special items

Total assets

Long-term debt

Shareholder's equity

AIR CARRIER TRAFFIC STATISTICS

Revenue passenger-miles

Revenue ton-miles

Available seat-miles

Stage length

Aircraft revenue hours

AIRLINE OPERATING STATISTICS

Employment

WORLD AVIATION DIRECTORY & TRANSPORT WORLD

Fleet size

STANDARD & POOR'S INDUSTRY SURVEYS - AIR TRANSPORT

Load factor -- actual ton-mile

Load factor -- break-even

4.1 Specification 1

This specification was based upon quarterly observations covering the period first quarter 1968 through second quarter 1975. Utilizing a standard, additive, linear regression, several dependent (or response) variables were regressed against various combinations of independent variables drawn from the factors of Section 3.

For the initial regression two carriers, Delta and Eastern, were

used because of the similarity of their route systems and the fact that they represented extreme points in terms of profitability (Delta - high, Eastern - low).

In addition, for each carrier various measures of profitability (discussed below) and alternate methods of quantifying certain independent variables were tested. Specific details for each of these measures are discussed later in this section.

The dependent variable can be measured in one of several ways:

DEPENDENT VARIABLES

Profit margin (PM)*

Return on total assets* (ROA)

Return on equity* (ROE)

Return on invested capital (RTNIN)

where $RTNIN = \frac{\text{net income (after special items but before interest)}}{\text{invested capital}}$

and invested capital = long-term debt + shareholders' equity

Again, relying on the discussion in Section 3, independent variables were selected and quantified as described in the following section.

*Defined in Section 3.2, pp. 84-87

4.1.1 Independent Variables

4.1.1.1 Competition

On the assumption that each carrier will be attempting to maximize its market share and hence profits in its top ten markets, an aggregate measure was developed based upon traffic in these city pairs. As a high market share in a dense market would impact more heavily on profitability than an equal market share in a less dense market, a weighted average was used. Selection of markets was based upon a variety of factors including route density, stage length, and the market's relationship to the carrier's overall system.

Defining:

i = index of a carrier's top ten markets

j = index of carriers

T = total number of carriers serving market i

RP_{ij} = number of revenue passengers carried in market i by carrier j

RP_i = number of revenue passengers carried in market i by all carriers

Then:

$$RP_i = \sum_{j=1}^T RP_{ij}$$

Further defining

TRP_j = total number of revenue passengers flown in all of carrier j's top ten markets by all carriers

$$TRP_j = \sum_{i=1}^{10} RP_i$$

Lastly :

MS_{ij} = carrier j's market share in market i

$$CMP_A = \sum_{i=1}^{10} (RP_i / TRP_j) \times MS_{ij}$$

In addition, revenue passenger-miles were also substituted for revenue passengers in a second specification. So that

$$CMP_B = \sum_{i=1}^{10} (RPM_i / TRPM_j) \times MS_{ij}$$

4.1.1.2 Length of Haul

Average domestic stage length.

4.1.1.3 Density

Again using a carrier's top ten markets, a ratio was formed by dividing the total revenue passengers carried by all carriers in carrier j's top ten markets by the total revenue passengers in the top ten domestic markets in the U.S.

$$D = \frac{TRP_j}{TRPT}$$

TRP_j = as defined before

$TRPT$ = total revenue passengers in top 10 markets in the U.S.

4.1.1.4 Concentration

Aggregation of traffic demand into a small number of markets should allow for concentration of aircraft in these markets.

Therefore

$$CONC = TRP_j / RP_j$$

TRP_j = as defined

RP_j = as defined

Revenue passenger-miles were also substituted for revenue passengers in both numerator and denominator.

4.1.1.5 Seasonality

Several methods were available to measure the factor of seasonality. Each was tested in various calibration attempts.

- (a) Seasonality = $\frac{\text{revenue passengers in peak month of quarter}}{\text{revenue passengers in minimum month of quarter}}$
- (b) " = $\text{passengers in peak month} - \text{passengers in minimum month}$

4.1.1.6 Yield

The factor of yield is simply revenue per revenue passenger-mile on scheduled services, i.e.,

$$YLD = \frac{\text{passenger revenues}}{\text{revenue passenger miles}}$$

4.1.1.7 Utilization

Allowing for the fact that various aircraft are not distinguished from each other, utilization per day is = $\frac{\text{aircraft revenue hours}}{\text{total fleet} \times 90}$

4.1.1.8 Equipment Quality

With certain misgivings and qualifications, depreciation expense was used as a surrogate for this variable. Since depreciation is a function of several factors (age, cost, arbitrary depreciation schedules, salvage value, aircraft type), the variable is viewed, at least as presently quantified, with some skepticism.

4.1.1.9 Management Quality

Again, general and administrative costs were used as a surrogate for this important, yet almost intangible quality.

4.1.1.10 Advertising

The variable of advertising was measured in a variety of ways in order to capture the influence of additional advertising dollars. Promotion and sales expense, which covers a broader scale than pure advertising, was used and this fact was not considered to seriously affect the influence of product differentiation that was trying to be captured.

$$ADV = \frac{\text{revenue passengers}}{\text{promotion and sales expense}}$$

4.1.1.11 Financial Status

A variety of ratios are available that measure several aspects of a firm's financial strength.

- (1) Leverage = debt/shareholder's equity
- (2) Interest coverage = gross income/interest expense
- (3) Liquidity = current assets/current liabilities
- (4) Debt service = interest expense/operating expenses
- (5) Value = $\frac{\text{market value per share common stock}}{\text{book value per share common stock}}$

Results of regressions for Delta and Eastern are given in Table 4.1 together with a description of each term in Table 4.2.

Despite the acceptable R^2 , the remaining summary statistics indicate the need for adjustments and modifications to this specification (low F statistic, high standard error). It is felt that much of the difficulty can be attributed to the high degree of multicollinearity that exists between

TABLE 4.1 RESULTS OF REGRESSION RUNS
FOR EASTERN AND DELTA

Variable	EASTERN	
	Run 1 Coeff. (t)	Run 2 Coeff. (t)
CMPA	0.508 (1.51)	--
CMPB	--	-0.182 (-1.73)
L ₁	0.0011 (1.45)	7.88 (2.85)
D ₁	0.604 (2.02)	-0.408 (-0.743)
CONC ₁	-0.4703 (-0.89)	--
CONC ₂	--	0.510 (2.04)
U	-0.76E-5 (0.030)	0.035 (0.21)
UTIL	--	--
Y	2.62 (1.82)	-0.272 (-0.40)
MQ	-4.02 (-0.088)	--
A	1.76 (1.90)	1.93 (1.39)
DS	3.26 (1.31)	-0.953 (-0.59)
E	-2.36 (-1.10)	- .0159 (-0.50)
EQUIP	--	--
SEAS ₁	-0.03 (-0.21)	--
CONSTANT	-1.54 (-2.06)	0.000285 (2.69)
R ²	0.70	0.82
F	1.97	2.10
Std. error	0.0317	0.0320
D-W	1.72	1.79
Mean of PM	0.0324	0.0392

TABLE 4.1 (concluded)

DELTA		
Variable	Run 1 Coeff. (t)	Run 2 Coeff. (t)
CMPA	0.164 (0.388)	--
CMPB	--	-0.585 (-2.78)
L ₁	0.000173 (0.786)	-0.286 (-0.63)
D ₁	1.15 (2.31)	-0.844 (-0.287)
CONC ₁	-0.23 (-3.40)	--
CONC ₂	--	-0.556 (-1.69)
U	88.90 (2.28)	-0.176 (-2.08)
UTIL	--	--
Y	-1.11 (-0.91)	0.163 (1.01)
MQ	-0.105 (-1.21)	--
A	0.856 (1.62)	1.15 (2.18)
DS	-0.267 (-0.016)	-2.42 (-1.50)
E	-0.880 (-1.56)	-1.64 (-2.93)
EQUIP	--	--
SEAS ₁	-0.631 (-0.86)	--
CONSTANT	-.213 (-0.31)	0.672 (1.40)
R ²	0.82	0.80
F	3.73	4.94
Std. error	0.0282	0.0268
D-W	2.46	2.09
Mean of PM	0.118	0.118

TABLE 4.2 VARIABLE DESCRIPTION

$$CMPA = \sum_{i=1}^{10} \frac{RP_i}{TRP_j} MS_{ij}$$

$$CMPB = \sum_{i=1}^{10} \frac{RPM_i}{TRPM_j} MS_{ij}$$

$$L_i = \sum_{i=1}^3 L_i / 3 \quad (L = \sum_{i=1}^3 L_i \text{ for one DL equation})$$

$$D_1 = \frac{TRP_j}{TRPT}$$

$$D_2 = \frac{TRPM_j}{TRPMT} \text{ where } TRPM_j = \text{total revenue passenger miles in carrier j's top ten markets, flown by all carriers}$$

TRPMT = total revenue passenger miles flown in top ten markets in U.S.

$$CONC_1 = TRP_j / RPEN_j \text{ where } RPEN = \text{revenue passenger enplanements by carrier j, all markets}$$

$$CONC_2 = TRPM / RPM_j \text{ where } RPM_j = \text{revenue passenger miles by carrier j in all markets}$$

$$SEAS_1 = \frac{\text{peak month enplanements}}{\text{minimum month enplanements}} \quad (\text{EA only})$$

$$SEAS_2 = \text{peak month enplanements} - \text{minimum month enplanements} \quad (\text{DL only})$$

$$U = \text{aircraft revenue hours/fleet size adjusted to be in hours/aircraft/day}$$

TABLE 4.2 (concluded)

UTIL = fleet size/aircraft revenue hours

E = direct maintenance costs/aircraft revenue hours

EQUIP = 1/depreciation expense

MQ = general and administrative costs/available seat miles

A = $RPEN_j$ /promotion and sales expense

DS = interest expense/transport expenses

Y = transport revenues/RPM

many of the variables. This would, in turn, cause high standard errors for the estimated coefficients ($\hat{\beta}_i$'s) and subsequently lower t-statistics.

Nevertheless, it is noted that for Run 1 of both Delta and Eastern, the D_1 (density) variable is positive and significant, indicating increased available traffic has caused profitability to increase, other things being held constant.

The variable CMPB, competition, is also relatively significant for both carriers and indicates that increased competition has reduced profitability, as one would expect from economic theory.

Lastly, advertising (A) shows results that indicate this factor could be of significant influence, perhaps slightly modified by a transformation. In this specification, one can tentatively assume that product differentiation, via promotion and sales effort, does influence profitability.

As mentioned earlier, several other potential measures for the dependent variable were formulated, as well as alternate quantifications for some of the independent variables.

Regression runs were also made using these variables in an attempt to develop a statistically stronger equation. No single criteria was used to measure this strength, but many factors were weighed. Among these were R^2 (multiple correlation coefficient), F statistic, standard error of the regression (SER), plus the sign and t statistic of individual estimates of coefficients. Combinations of variables were selected based upon the information provided in the regression output (the factors listed above plus the correlation matrix) and intuitive beliefs regarding the various factors. Since Delta and Eastern may represent erratic behavior, two additional

airlines (American and Braniff) were also calibrated.

Results of various runs are given in the next section.

4.1.2 Results

4.1.2.1 American

$$\text{RTNIN} = -.14 + .0106 \text{ UTIL} - .0051 \text{ ADV} + .0023 \text{ LEVG} + .125 \text{ LGTH}$$

(1.8) (-1.1) (.34) (1.9)

$$- .12 \text{ CMP}_1 + .044 \text{ DNSTY} - .0022 \text{ YLD} \quad (4-1)$$

(-.93) (.79) (-.44)

$$R^2 = .60 \quad F = 2.6 \quad \text{SER} = .010 \quad \text{DW} = 2.19 \quad \text{MEAN OF RTNIN} = .0035$$

4.1.2.2 Braniff

$$\text{RTNIN} = - .12 + .004 \text{ UTIL} + .0024 \text{ ADV} - .0038 \text{ LEVGE} + .034 \text{ LGTH}$$

(1.82) (2.74) (-.87) (1.4)

$$+ .024 \text{ CMP}_1 + .137 \text{ DNSTY} + .0032 \text{ YLD} \quad (4-2)$$

(.65) (1.98) (1.27)

$$R^2 = .88 \quad F = 13.2 \quad \text{SER} = .0028 \quad \text{DW} = 2.86 \quad \text{MEAN OF RTNIN} = .0152$$

4.1.2.3 Delta

$$\begin{aligned} \text{ROE} = & .05 + .035 \text{ ADV} - .032 \text{ YLD} - .001 \text{ VALUE} - .208 \text{ CMP} & (4-3) \\ & (2.2) \quad (-2.5) \quad (-.07) \quad (-2.7) \\ R^2 = & .49 \quad F = 3.9 \quad \text{SER} = .024 \quad \text{MEAN OF ROE} = .068 \end{aligned}$$

4.1.2.4 Eastern

$$\begin{aligned} \text{ROA} = & - .104 + .005 \text{ ADV} + .049 \text{ DNSTY} - .004 \text{ LEVGE} + .003 \text{ VALUE} \\ & (3.3) \quad (2.0) \quad (-1.0) \quad (1.2) \\ & + .083 \text{ CMP} & (4-4) \\ & (3.0) \\ R^2 = & .69 \quad F = 6.7 \quad \text{SER} = .0049 \quad \text{MEAN OF ROA} = .0067 \end{aligned}$$

The results given here are not the only specifications that were tested. Various combinations of dependent and independent variables were tested with equally poor results.

In general, the additional airline results are consistent with the initial calibrations. While the R^2 are acceptable, and several variables are significant and of the expected sign, high standard errors of the regressions and low F statistics persist. Of the significant variables, advertising remains the strongest, although the problems of multicollinearity can be causing the t statistics of individual variables to be reduced.

4.2 Specification 2

Specification 2 was tested in an effort to address several of the shortcomings of specification 1 by retaining, when possible, those factors that had performed well and, at the same time, adding measures that were not explicitly included in the model.

4.2.1 Modifications to Specification 1

The first major modification was the shift to annual observations in place of a quarterly time period. It was felt that annual observations would eliminate many of the seasonality biases that existed previously, and would better relate the decision variables that were being used to the profit maximizing goal of the management.

4.2.1.1

Both density and competition could not be used due to data availability. Although competition was significant in one specification for Delta and another for Eastern, it did not perform well in later specifications for either American or Braniff. In addition, as alternative measures of profitability were tested, the competition variable often became negative (which is contrary to economic theories of firm behavior) or insignificant for an airline for which it had previously been acceptable.

Consequently, it was felt that the competition variable, as presently measured, lacks the robustness necessary for continued inclusion in the model. Re-examination and calibration of this variable are among the several steps that should be considered to strengthen the model.

As mentioned above, data limitations forced elimination of the density variable as it was presently measured. In this specification various measures of individual airline activity, such as total departures, enplaned passengers and total revenue passenger-miles were substituted as instrumental variables in lieu of density. While the results were generally below acceptable standards, the variable was carried, in concept, to specification 3 where the results were generally more encouraging.

4.2.1.2

Additional explanatory variables were added to include several of the factors discussed in Section 3 that were not used in the quarterly specification.

4.2.1.2a Costs

In general this variable represents the impact of increased airline productivity on unit costs due to the introduction of faster, larger aircraft, and more recently due to automation in some ground services. While in some cases the reduction in cost was lost to increased wages, or fuel, or more flights, other airlines have been able to capitalize on the trend of cost reductions shown earlier in Figure 2.1. This variable measures the average

cost per unit of output and is equal to operating expenses per available ton-mile.

4.2.1.2b Labor Efficiency

As discussed in Section 3, increased labor productivity indicates more production use of labor inputs with the corresponding reduction in cost due to fewer salaries needing to be paid. This variable implicitly measures the carrier's ability to effectively manage and motivate its employees by measuring the number of available ton-miles "produced" by each.

4.2.1.2c General Traffic Growth

This variable, general traffic growth, measures the trend in passenger growth that has prevailed over the past ten years and assumes that a certain portion of each airline's change in profits has been the result of this trend. Although most forecasts have proven to be woefully inadequate, those airlines that can accurately predict this growth and match their capacity to the traffic level can take advantage of the higher operating leverage that exists in the industry.

4.2.1.2d Macroeconomic Activity

Both the inability to inventory output and the fact that air travel is a derived demand make airlines highly susceptible to fluctuations in the national economy. In this case several aggregate measures, as well as some more closely tied to average individual economic well-being, were tested in order to track the influences of the business cycle on the fortunes of the airlines. The measures used included:

- (1) Gross National Product (Real and Nominal) as a measure of the overall strength of the economy as a whole.

(2) Gross National Product Per Capita (Real and Nominal) normalizes GNP so as to measure increased output per capita that would result from higher business production and not merely more activity.

(3) Personal Consumption Expenditures. This measure views the overall economy from the opposite side of the equation and measures the economy's well-being from the point of view of individual willingness to purchase goods and services rather than save. In the belief that increased consumer activity stimulates business activity, which increases the desire for business and pleasure travel, increased personal consumption translates into higher demand for air travel.

(4) Money Supply (M2). This measure is defined as cash, coin, bank deposits, and time deposits; the supply of money is closely tied to fluctuations in GNP and interest rates. Increased M2 will lower interest rates, while a larger GNP will increase the demand for money. Although the money supply is controlled by the Federal Reserve Bank, it was felt that an increase in the money supply will signal a stronger economic situation and will result in increased demand for the airlines.

4.2.1.3 Data Base Expansion

A last major change to this specification of the model involved expanding the available data base to include both time series and cross-section observations. However, since data pooling requires one to assume that the cross-section parameters remain constant over time, it was considered necessary to reduce the original time frame that we considered.

Specifically, the time frame 1957-1975 represents one of considerable change in airline fleet composition, as the carriers moved to all-jet fleets. This, in turn, caused the model to deal with major changes in underlying cost functions, aircraft scheduling, utilization and other factors. Consequently, for specification 2 the time period is reduced to include only 1965-1975.

4.2.2 Approaches to Pooled Regression

Various approaches are available to deal with the specification of pooled cross-section and time series data. First, ordinary least squares can be performed on the entire data set. Second, one might assume that omitted variables may lead to changing cross-section and time series intercepts; as a result a binary variable can be added for each cross-sectional unit and each time period. This, of course, results in some loss in degrees of freedom when the calibration process begins. This is often referred to as a covariance model. Third, one can employ the so-called "error-components" model that essentially assumes the error term of the regression can be divided into a times series component, a cross-section component, and an overall component.¹

In other words

$$e_{it} = u_i + v_i + w_{it}$$

where

u_i = the time series component

v_i = the cross-sectional component

and

w_{it} = the time series and cross-sectional components

It is also assumed that each element is distributed according to a Gaussian distribution with zero mean and variance equal to σ_u^2 , σ_v^2 , and σ_w^2 , respectively. And lastly, as with ordinary least squares, each component is not serially correlated nor correlated with another element; consequently, e_{it} is homoscedastic.

The error components model assumes that the mean effect of the random time series and cross-section variables of the covariance model is included in the intercept term and the random deviations about the mean are equated to the error components u_i and v_i .²

For the purposes of this study, the first two approaches will be used as an initial approximation of the true specification of the model.

As was the case with specification 2, additions and modifications to the response and carrier variables were also investigated so as to allow for evaluation of the numerous factors that were discussed in Section 3.

In this case, operating profit, or cash flow, equal to total transport revenues less operating expenses, is used as the response variable. Since firms evaluate investment alternatives based upon expected cash flows from that project, sellers of goods can measure potential customer willingness and ability to purchase their product by evaluating the change in the buyer cash flow their product will produce. For example, airframe manufacturers determine their production schedules and decisions based upon future sales of aircraft. An airline's decision to purchase a given airplane is the result of an evaluation of the net impact or cash flow of a given aircraft.

Historically, new aircraft have meant increased productivity and lower operating costs per seat mile.

4.2.2.1 Additional Independent Variables - 2

In addition to evaluating operating profit as the dependent variable, several new independent variables were added to the model specification.

These included:

4.2.2.1a Non-Scheduled Revenue Ton-Miles

In this case the assumption is that airlines that fly a large number of nonscheduled flights (normally charters) will reduce their overall yield since this type of service is flown at discounted prices. On the other hand, charter flights are generally undertaken in times of slack scheduled demand and, thus, as long as the yield covers variable costs (fuel and landing fees), they make a valuable addition to total profits. Some international charters, however, are conducted on a "regular" basis at prices that make no contribution to the fixed costs.

4.2.2.1b Actual Load Factor

As defined earlier, this factor represents the ability of management to match capacity with expected and realized demand. A carrier can influence its load factor by attracting additional traffic due to effective advertising or aircraft scheduling, or it can adjust the size of aircraft serving a given city pair. Of course, if size or frequency fall too low, passengers are turned away to the competition.

4.2.2.1c Break-Even Load Factor

Defined to be the point where costs are just covered by revenues, the break-even load factor ratio is a function of the average cost of producing the schedule of flights and the revenues that are generated by these flights.

4.2.2.2 Preliminary Results -- Pooled Time Series and Cross-Section

As an initial regression, the following results were obtained:

$$\begin{aligned} \text{PROFIT} = & .102 \text{ ADV} + 7666 \text{ LFA} - 9609 \text{ LFB} - 320 \text{ LABOR} \\ & (.83) \quad (4.09) \quad (-4.72) \quad (-1.87) \\ & + 69.3 \text{ GNP} - 234338 \quad (4-5) \\ & (2.8) \end{aligned}$$

$$R^2 = .22 \quad \text{SER} = 54816 \quad \text{DW} = 1.01 \quad \text{MEAN OF PRFT} = 47222.6 \quad F(5.94) = 5.41$$

One immediately notices the low R^2 and the high value for the equation's standard error. This is probably due to heteroscedasticity, or nonconstant errors across observations, which is a common difficulty when dealing with cross-sectional data. Also, when one considers the volatility of the airlines' profits, such a result is not surprising (see Table 4-3).

Lastly, the DW statistic indicates that in addition to nonconstant errors, serial correlation is also present.

With respect to individual terms, somewhat surprising is the low t statistic for the ADV term that previously had been significant in other specifications. No explanation is immediately evident for this result.

Concerning the other terms, all are significant and of the expected sign with the possible exception of LABOR (i.e. labor efficiency = available

TABLE 4.3 OPERATING PROFITS(\$000) 1965-1975
DOMESTIC TRUNK AIRLINES

	Mean	Standard Deviation
AA	46,832.9	41,850.7
BN	21,607.5	10,591.3
CO	24,402.3	8,689.9
DL	85,878.5	27,798.9
EA	55,356.7	69,364.7
NA	85,119.7	128,342.5
NW	56,836.4	47,422.9
TW	6,962.3	59,979.1
UA	73,758.6	47,238.9
WA	19,114.4	14,295.7
A11 Trunks	47,222.6	60,316.6

ton-miles per employee). While one would expect an increase in labor productivity to result in increased cash flows, the negative sign indicates the opposite. Only if output reached excessive levels would excess capacity (or productivity) produce reduced cash flows. As the airlines are often accused of excess competition in the form of added frequencies, perhaps the negative sign is not totally erroneous.

Calibration of the model using a binary variable for each airline did not improve the equation's statistical strength and did not contain any significant terms among the various firm's "dummy" variables. Although the results are not reproduced here, the values for the firm intercepts varied widely, illustrating the considerable variation in the profitability of individual airlines.

4.2.3 Mallows C_p Criteria

Several techniques exist that can be used to further analyze the data set. However, rather than employ these methods on the specification of equation 4-5, it was considered more prudent to once again modify the list of response variables and employ a method that selects the "best" subset of explanatory variables.

Simply, this technique, known as Mallows C_p criteria, selects this best subset from a given list of carriers by measuring the "total squared error" as estimated by the C_p statistic. That is, the C_p statistic measures the sum of the squared biases plus the squared random errors in Y so that

$$C_p = \frac{RSS_p}{S^2} - N + 2p$$

where

RSS_p = residual sum of squares with p terms in the equation

S^2 = estimate of σ^2 , the population variance

N = number of data points

p = number of parameters

In using the C_p criteria, one looks for subsets of variables that generate a value of C_p near p (i.e. there is little bias) and C_p is itself small.³

4.2.3.1 Other "Stepwise" Algorithms

Several other so-called "stepwise" algorithms are available to analyze various subsets of variables. However, these procedures need to be viewed with caution. For example, in a forward stepwise procedure an independent variable is selected based upon its partial correlation with the dependent variable; when a successive variable is selected, the partial correlation of each variable in the equation is calculated, given the other variables that are present; if one of these term's partial correlation is below a given level, that variable is removed from the specification. This creates the situation where, for example, x_2 can be eliminated because its partial correlation with the dependent variable y is decreased because of the addition of a highly correlated second variable x_3 . However, if x_3 is subsequently eliminated, x_2 is not reintroduced and the cause for x_2 's

elimination is no longer present.

By utilizing the C_p criteria this difficulty is avoided, more than one specification is offered as being among the "best" and the model builder is allowed a certain amount of latitude in determination of the model.

Since computer software is available to easily perform regressions on subsets of parameters and calculate the corresponding C_p statistics, it is easy to quickly calibrate the set of "best" regression from which the most effective can be selected.

4.2.3.2 Additional Independent Variables

Before this selection procedure was conducted, a few modifications were made to the list of explanatory variables.

4.2.3.2a GNP

Although GNP was significant in equation 4-5, throughout the calibration process there have been difficulties with multicollinearity between it and other variables. While the results of equation 4-5 are encouraging, another measure was substituted for GNP in order to avoid these difficulties.

4.2.3.2b Revenue Passenger-Miles

In lieu of GNP, changes in total industry revenue passenger-miles was chosen to represent the influence of changing macroeconomic activity on the airline industry. Measured as both a percent and a cardinal value, passenger travel can be assumed to reflect both the business and pleasure traveler's response to fluctuations in the economy.

4.2.3.3 Results Using the C_p Criteria

Among the specifications selected was the following:

$$\begin{aligned} \text{PRFTA} = & - 1416.74 + 9.459 \text{ADVA} - 22.77 \text{ATMTA} - 34.77 \text{NSATMA} \\ & (2.87) \quad (-2.77) \quad (-5.38) \\ & + 223.51 \text{YLD} - 118.56 \text{AVCOST} - 151.72 \text{LEVGE} + 73.55 \text{LFA} \\ & (3.43) \quad (-8.97) \quad (-2.29) \quad (6.59) \quad (4-6) \\ R^2 = .55 \quad \bar{R}^2 = .52 \quad F = 16.41 \quad \text{SER} = 419.3 \quad \text{MEAN OF PRFTA} = 472.22 \end{aligned}$$

where

PRFTA = operating profit (10^5)
 ADVA = promotion and sales expense (10^6)
 ATMTA = total available ton-miles (10^8)
 NSATMA = non-scheduled available ton-miles (%)
 YLD = yield (¢/RPM)
 AVCOST = average cost (¢/ATM)
 LEVGE = debt to equity ratio
 LFA = actual load factor

Ironically, neither measure of growth was selected in this specification.

Otherwise, the specification is quite satisfactory.

(1) Considering the fact that pooled observations are used, an \bar{R}^2 of .52 is not unreasonable.

(2) The standard error of the regression, while still high relative

to the mean, is less than the standard error for operating profits of the industry (see Table 4.3).

(3) Individual variables are significant and of the proper sign.

(a) A one-cent improvement in yield will cause a larger increase in operating profits than the corresponding decrease due to a one-cent increase in costs.

(b) Although leverage does not directly affect operating profits in the present period, past and current investment decisions do depend on financing. As a result, many airlines have been forced to forego investment opportunities because their financial structure has created excessive risk and raised their cost of capital. In that this prevents expansion or modernization, it can potentially reduce operating profits.

(c) A 1% increase in actual load factor can raise operating profits by \$7 million. On average, this is probably a reasonable number.

4.2.4 Evaluation of "High Leverage" Data Points

Following an initial specification by least squares, it is worthwhile to determine if single observations exert unusual influence or leverage on the calibration of the model. Although this is normally accomplished by examining bivariate scatter plots, when the number of parameters exceeds two these plots are less than clear.

As an alternative, it is possible to use the "hat matrix" to identify high leverage points (see Appendix C). Employing this technique on the present data set reveals the high leverage points given below.

Continental	=	1966, 1967	
Delta	=	1974*	
Eastern	=	1966*, 1967*, 1974	
National	=	1973, 1974	
Northwest	=	1972	
TransWorld	=	1970*, 1974*	* points with standardized residuals >2
United	=	1973*	

In addition, discrepant values can also be detected by examining the standardized residual for each observation and considering the elimination of those with $r' > 2$.

Ideally, having identified points as high leverage observations, they should be investigated individually to determine if any adverse effects result when the equation was fit. In other words, arbitrary elimination of observations can reduce the precision with which coefficients are estimated.

Despite this caveat, due to external limitations and the belief that as a first cut the impact of removing all twelve points would be minimal, this was the procedure that was followed. After an initial run it was found that the ATM variable was not significant, so that it was removed as well. This then resulted in the following equation:

$$\begin{aligned}
 \text{PRFT} = & - 1163.8 + 10.14 \text{ ADV} - 20.97 \text{ NSATM} + 109.31 \text{ YLD} \\
 & \quad (3.5) \quad (-2.16) \quad (4.54) \\
 & - 61.81 \text{ AVCOST} + 54.16 \text{ LFA} - 160.92 \text{ LEVGE} \quad (4-7) \\
 & \quad (-4.54) \quad (6.23) \quad (-3.3) \\
 R^2 = & .46 \quad F = 11.77 \quad \text{SER} = 279.59 \quad \text{MEAN OF PRFT} = 411.36 \quad \text{DW} = 1.65
 \end{aligned}$$

While elimination of the discrepant, high leverage points reduces the SER from that of equation 4-6, the change in the coefficients of YLD, AVCOST, and LFA exceeds one standard deviation of their estimate and would therefore warrant closer scrutiny of individual observations than was conducted here.

In any event, the latter equation seems to represent an improvement over the previous one.

4.2.5 Heteroscedasticity

As was mentioned previously, when dealing with cross-sectional data heteroscedasticity is often a problem. One possibility is to transform the data by dividing each observation by the standard error of the residual that was obtained from the least squares solution. This, in turn, results in error terms that have constant variance.⁴

4.2.6 Autocorrelation

Since the model also contains time series observations, it also becomes necessary to consider the problem of autocorrelation. As discussed previously, several techniques are available to deal with autocorrelation such as Cochrane-Orcutt (employed here) and others.⁵

In testing the ability to correct for these conditions, first heteroscedasticity was addressed, then serial correlation, then both.

Adjustment for Heteroscedasticity

$$\begin{aligned} \text{PRFT}' &= - 2.02 + 3.35 \text{ ADV}' - 6.14 \text{ ATM}' - 21.5 \text{ NSATM}' + 100 \text{ YLD}' \\ &\quad (1.08) \quad (-.78) \quad (-3.5) \quad (1.94) \\ &\quad - 70.25 \text{ AVCOST}' - 166.26 \text{ LEVGE} + 52.0 \text{ LFA} \quad (4-8) \\ &\quad (-3.91) \quad (-3.36) \quad (5.98) \\ R^2 &= .45 \quad \text{SER} .70 \quad F = 9.57 \quad \text{MEAN} = 1.01 \quad \text{DW} = 1.65 \end{aligned}$$

The high standard error and the large changes in coefficients tend to make these results subject to some doubt.

Adjustment for Serial Correlation

Using the Cochrane-Orcutt technique to re-estimate equation (4-7) gives the following results:

$$\begin{aligned} \text{PRFT}^* &= - 1310.75 + 12.35 \text{ ADV}^* - 21.63 \text{ NSATM}^* + 121.29 \text{ YLD}^* \\ &\quad (1.76) \quad (-3.27) \quad (2.16) \end{aligned}$$

$$- 64.49 \text{ AVCOST} - 164.28 \text{ LEVGE}^* + 56.78 \text{ LFA}^* \quad (4-9)$$

(-4.28) (-3.0) (5.82)

$$R^2 = .47 \quad F = 12.28 \quad SER = 276.47 \quad DW = 2.08 \quad MEAN = 407.63$$

where

$$\begin{aligned} \text{PRFT}^* &= \text{PRFT} - \rho \text{PRFT} - 1 \\ \text{ADV}^* &= \text{ADV} - \rho \text{ADV} - 1 \\ \text{NSATM}^* &= \text{NSATM} - \rho \text{NSATM} - 1 \\ \text{YLD}^* &= \text{YLD} - \rho \text{YLD} - 1 \\ \text{AVCOST}^* &= \text{AVCOST} - \rho \text{AVCOST} - 1 \\ \text{LEVGE}^* &= \text{LEVGE} - \rho \text{LEVGE} - 1 \\ \text{LFA}^* &= \text{LFA} - \rho \text{LFA} - 1 \\ \rho &= .187 \\ &(1.77) \end{aligned}$$

Based upon the results of equation 4-9 it would appear that elimination of the serial correlation is much more effective in improving the forecasting ability of the specification than is correcting for heteroscedasticity. Although the standard error is still larger than one would ideally hope for, again given the volatility of the industry's profits and the earlier results, equation 4-9 is a better forecasting tool.

NOTE: R^2 Statistic

A note should be added at this point concerning the R^2 statistic for this equation. When dealing with time series data, one normally finds a

higher R^2 because one variable growing over time is likely to do a good job explaining another variable growing over time. However, in cross-section regressions, a low R^2 does not necessarily indicate an unsatisfactory model since the variation across observations is much larger, thereby reducing the percent of the variation explained by the same subset of variables. The R^2 statistic is only one of several variables used to evaluate a given regression and it should not be considered the ultimate test of a specification's strength to forecast given new data.

4.2.7 Correction for Serial Correlation and Heteroscedasticity

This estimation simply combines the procedures of (1) data transformed by dividing each observation by the residual standard error and (2) adjustment for serial correlation using Cochrane-Orcutt. However, since the results of these modifications did not differ significantly from those of specification 4.8 they will not be repeated here.

As a result of these modifications, the strongest specification would appear to be the pooled time series cross-section model that eliminates high leverage points and contains a correction for serial correlation. Given the relatively low SER and strong explanatory variables, this model should provide better forecasts than the previous specifications.

4.2.8 Individual Airline Equations

In contrast to the final portion of the preceding section, where the model was calibrated based upon pooled data, in this section we return to the task of estimating an equation for each individual airline.

Once again using the C_p criteria, a model is selected from the designated "best" regressions and used not only as a forecasting tool for each airline, but also as a means of comparing one air carrier with another. Table 4.1.1 gives the set of independent variables that were considered.

While variables remain essentially the same as earlier specifications (Section 4), minor modifications were made based upon available data. These changes are not considered serious. In addition, the period of observation for individual trunks was re-established to 1957-1975. Although the problem remains concerning the impact of fleet modernization on airline operations and management, it is considered less serious than in the pooled data set. Given the paucity of observations for each trunk airline, the need to expand the data base was considered more important than the problem of jet additions. Rather than discuss the variables for each carrier individually, the results for individual airlines will be given first, following which will be an evaluation of the separate terms.

TABLE 4.1.1 INDEPENDENT VARIABLES

Advertising (AD)	= promotion and sales expense x (10^6)
Yield (YLD)	= passenger revenue per revenue passenger mile (¢)
Leverage (LEVGE)	= debt to equity ratio (book values)
Labor productivity (LABOR)	= available seat mile/employee
Average cost (AVCOST)	= operating expense/available seat mile
Actual load factor (LFA)	= revenue passenger miles/available seat miles
Money supply - M2 (MS)	= coin and currency plus time deposits plus demand deposits
Passenger growth (GROWTH)	= increase or decrease in revenue passenger miles
% passenger growth (PERCENTG)	= percent change in revenue passenger miles

TABLE 4.1.2 INDIVIDUAL AIRLINE COEFFICIENTS AND t-STATISTICS

CARRIER	ADV	YLD	LEVGE	LABOR	AVCOST	LOAD FACTOR	M2	GROWTH	% GROWTH
AA	-24.1 (-3.19)	976.1 (6.9)	--	--	-1186 (-4.0)	97.9 (5.7)	13.3 (2.9)	.369 (2.0)	-31.1 (-2.2)
BN	7.26 (3.13)	--	-25.7 (-2.0)	-.76 (-4.4)	-142.7 (-3.3)	10.8 (3.0)	3.1 (7.2)	-.09 (-4.1)	--
CO	-11.6 (-3.77)	--	--	--	--	15.0 (2.3)	3.0 (5.2)	--	-3.9 (-.91)
DL	16.3 (3.96)	761.9 (4.3)	333.2 (2.9)	-3.4 (-4.7)	-2029 (-6.2)	57.8 (5.6)	6.1 (1.9)	-.30 (-2.5)	--
EA	--	582.8 (2.4)	--	--	-1213 (-4.1)	62.9 (4.0)	1.5 (2.0)	--	--
NA	--	--	576.6 (2.8)	--	-1113 (-16.0)	47.5 (3.3)	--	--	--
NW	--	--	451.2 (1.3)	--	-1372 (-4.9)	72.6 (4.3)	16.8 (2.6)	-.53 (-1.7)	--
TW	-19.48 (-5.28)	871.0 (5.8)	-17.6 (-2.2)	1.49 (2.8)	-930 (-3.9)	40.5 (1.8)	6.2 (2.5)	.75 (3.8)	-21.1 (-1.6)
UA	10.5 (7.03)	2270 (8.1)	470.9 (2.6)	--	-4021 (-9.6)	287.1 (8.1)	--	--	--
WA	--	246.5 (3.2)	--	--	-498 (-6.3)	39.2 (6.9)	.70 (2.7)	.15 (2.1)	-18.8 (-3.1)

4.2.9 Analysis of Individual Variables

4.2.9.1 Advertising

The variable of advertising appears in six of the ten equations for the trunk airlines. For Braniff, Delta, and United, the sign is positive and would imply that increased advertising has had a positive effect upon operating profits. If size of coefficients is any indication, Delta's advertising could be assumed to be more effective as it would have a larger incremental influence on the size of profits.

In contrast, American, Continental and Trans World have negative coefficients in their calibrated equations, indicating that increased advertising has not only failed to generate additional traffic, but has actually reduced operating profits. Although this conclusion is somewhat questionable, TWA's "Lasagne Over L.A." campaign with a high-priced movie personality and Continental's "We Move Our Tail" have been found offensive by many people and not pertinent to the product attributes that the public is purchasing. Of course, the specification may be improper and erroneously causing the improper sign.

Insofar as those carriers where advertising does not appear (EA, NA, NW, WA), there is no immediate explanation for this absence.

4.2.9.2 Yield

The "yield" term appears in the equations of the so-called Big Four (AA, EA, TW, UA) plus Delta (now included in the "Big Five"), and Western. While yields are, of course, critical to any form, it is interesting to note that the large carriers are at least statistically connected to this variable. With their large capital investment, and operating leverage, these airlines are potentially confronted with more sparse routes, increased scheduling problems, increased costs and heavier reliance on higher yields to break even.

4.2.9.3 Leverage

Although leverage, or the financing mix of the firm, does not directly impact upon operating profits, financial policy does impact upon past and future investment decisions and the firm's ability to expand or modernize fleets. Interestingly, the three carriers with the lowest percent of their capital in long-term debt (DL - 36%, NA - 34%, NW - 15%) have positive coefficients on the leverage variable. This would seem to say that these carriers have been able to resort to debt issues on a limited basis; have thereby avoided high interest expenses and used equity financing to support fleet additions. Because they can use debt to increase stockholders' returns without approaching a state of financial distress, these carriers have been able to better match aircraft operating characteristics and costs with their route systems.

United Airlines also appears with a positive sign, and although their percent of debt capital is 54%, their finances have generally been in good enough shape to acquire the needed aircraft.

Of the two airlines with negative coefficients, one (TWA) is not at all surprising given its debt level of 71%, while the second (Braniff) is somewhat of a mystery. Also in doubt is why this variable did not enter the equation for Eastern, with a debt level of 63%.

4.2.9.4 Labor Efficiency

The results of the variable for labor efficiency are felt to be as much a result of the carrier's route structure as the productivity of the carrier's employees. TWA, for example, with long domestic and international routes, obtains a positive coefficient, while Delta and Braniff, with much shorter routes, are left with negative coefficients. On the other hand, Delta is frequently cited as a high labor-productive firm, free of much of the influence of unions.

4.2.9.5 Average Cost

The variable for average cost (AVCOST) appears in the estimation for all airlines except Continental. Once again, there is not an instantly obvious reason for the omission in that equation. In all other cases the variable is negative, as expected, and the coefficients range in value from -142 for Braniff to -4021 for United. Based upon the range of results, it

does not seem possible to attach any particular significance to the size of a given coefficient relative to a particular airline.

4.2.9.6 Load Factor

As would be expected, load factor increases cause operating profits to increase. Again, although it is difficult to attach any particular significance to the relationship between a given coefficient and the respective operating characteristics of the appropriate airline, some tentative inferences might be drawn concerning the nature of the load factor increases and their influence on profits. For example, American as a predominantly business-oriented carrier might expect increases in load factors to result in larger changes in profits since full fares (possible first class) will be paid. Or, taking Northwest with many long-haul monopoly routes, an increase in load factor would be expected to have a much larger effect.

And lastly, United with its large network could expect a system-wide improvement in load factor to have a large impact on profits; which the coefficient indicates it will.

4.2.9.7 Money Supply

As is often stated, the variable of money supply for the airlines tends to fluctuate quite significantly with the state of the economy. The results for all carriers (except National and United) confirm this factor. Why these

two were omitted is considered to be due more to statistical shortcomings in model specification than it is to lack of general correlation with the economy.

4.2.9.8 Growth

The variable for growth produces somewhat mixed results, since one would intuitively expect increases in revenue passenger-miles to result in increased profits. If a carrier were unable to absorb the increased traffic due to fleet limitations, a problem of inadequate supply would result. However, for the carriers with a negative coefficient (BN, DL, NW) this is not the case, and in fact, is quite the contrary.

4.2.9.9 Percent Growth

The results of the variable for percent growth seem to touch on a point made several times previously, that the airlines have generally had difficulty forecasting traffic growth, and have often been left with insufficient or excess capacity. As a consequence, rapid changes in traffic growth result in lost profits due to inadequate equipment.

4.3 Specification 3

As in specification 2, annual data for individual airlines were used, covering the period 1957 through 1975. Bearing in mind that forecasts of

profitability were to be produced using forecasts of independent variables, the following explanatory variables were dropped, either due to poor explanatory power or due to high correlation with other explanatory variables and difficulty in interpreting the coefficient sign:

- (a) Labor efficiency
- (b) Money supply
- (c) Growth
- (d) Percent growth

Explanatory variables retained were:

- (a) Yield
- (b) Leverage
- (c) Average cost
- (d) Load factor
- (e) Advertising

Two additional factors were tested, namely Revenue Passenger Miles (RPMS) and Non-Scheduled Revenue Passenger Miles (RPMNS). The dependent variable definition remained as total transport revenues less operating expenses. As before, Mallow's Cp criterion was used to select the "best" set of explanatory variables. A linear form of equation was appropriate for every airline except Continental, where a log-linear form was possible (the airline had a positive cash flow in every year) and significantly improved both fit and interpretative power.

4.3.1 Individual Airline Results

Coefficients, t-ratios and \bar{R}^2 values are given in Table 4.4.

Independent variables are defined as follows:

PRFT = (transport revenues - operating expenses) $\times 10^5$

YLD = ¢ per RPMS

AVCOST = ¢ per available seat mile

LEVGE = debt/equity ratio

LFA = actual load factor (%)

RPMS = scheduled revenue passenger miles

RPMNS = non-scheduled revenue passenger miles

\bar{R}^2 ranged from 0.73 for both American and Western to 0.97 for Northwest.

4.3.1.1 Yield

This variable appeared in every "best" equation but Braniff. A positive sign in front of the coefficient is to be expected, especially accompanied as it was for almost every year of the period, by traffic growth. There was a slight tendency for the big-four carriers' t-ratios to be higher than the rest, stressing the importance of yield changes to their performance.

4.3.1.2 Average Cost

This appeared (with negative sign) in all equations but Continental, and add T-ratios for National, Northwest, TWA and United were high.

4.3.1.3 Leverage

This factor was only significant in the case of Continental, where it had a negative coefficient and Northwest, where it had a positive coefficient. It is unclear exactly how leverage affects profitability. High leverage allows some airlines to make use of profitable investment situations that would not otherwise be possible, though at the higher cost of debt versus equity financing.

4.3.1.4 Load Factor

Load factor was significant for all airlines except Continental. All equations had a positive coefficient for this variable, which, assuming no change in yields, one would expect.

4.3.1.5 Scheduled Traffic

Changes in the level of scheduled RPMs were a factor in explaining changes in profitability for all airlines except Eastern and TWA. There was a particularly strong relationship in the case of Braniff. A positive

coefficient was observed in each case. Traffic growth had been achieved over most of the period by the positive stimulus of continuing GNP growth. If traffic growth can only be achieved by price cutting and yield dilution, increasing carrier market share in terms of economic and total market recession, this positive relationship between traffic and profitability would be expected to change radically.

4.3.1.6 Non-scheduled Traffic

This variable was included in the equations for Continental, Eastern, National and Northwest, in each case with a positive coefficient. This would be expected as long as the beneficial effect on costs through better utilization was not outweighed by yield dilution.

4.3.1.7 Multicollinearity

The individual airline equations were selected so as to reduce multicollinearity to a minimum, without too much loss of goodness of the overall fit. Individual simple regression coefficients (r) between independent variables were generally well below 0.80, though in some cases (EA) they exceeded 0.90 for the relationship between yield and average cost. This indicates that the airline may have followed closely a cost plus method of pricing, on the assumption that its target market was particularly price inelastic. Multicollinearity was generally acceptable for forecasting

purposes, though for analysis and control the model should be further improved.

4.3.2 Total Domestic Trunks

$$\begin{aligned}
 \text{PRFT} = & -62788.0 + 8891.1 \text{ YLD} - 14219.2 \text{ AVCOST} + 1044.3 \text{ LFA} \\
 & \quad (+5.88) \quad \quad (-7.47) \quad \quad (6.02) \\
 & + 1702.1 \text{ LEVGE} + 0.541 \text{ RPMNS} \\
 & \quad (1.70) \quad \quad (5.51) \\
 R^2 = 0.87 \quad \bar{R}^2 = 0.82 \quad F = 16.94 \quad C_p = 6.43
 \end{aligned}$$

The results for the domestic trunk aggregates over the same period were similar to the individual airline models, with the exclusion of RPMS. Multicollinearity was only present to any degree between yield and avcost ($r = 0.81$).

4.3.3 Comparison of Continental in Log and Linear Forms

$$\begin{aligned}
 \text{(a) PRFT} = & - 648.0 - 52.62 \text{ ADV} - 4791 \text{ LEVGE} + 241.2 \text{ AVCOST} \\
 & \quad (-3.28) \quad \quad (-2.43) \quad \quad (3.16) \\
 & + 0.413 \text{ RPMS} \\
 & \quad (3.48) \\
 C_p = 2.73 \quad F = 7.03 \quad R^2 = 0.67 \quad \bar{R}^2 = 0.57
 \end{aligned}$$

TABLE 4.4 TABLE OF COEFFICIENTS AND t-RATIOS

Dependent = PRFT

	YLD	LEVGE	AVCOST	LFA	RPMS	RPMNS
American	1435.93 (3.70)	--	-2277.03 (-5.46)	140.60 (4.71)	0.042 (2.43)	--
Braniff	--	--	-112.76 (-2.42)	19.95 (3.92)	0.089 (8.38)	
Continental*	5.077 (2.53)	-0.976 (4.12)	--	--	0.428 (2.24)	0.365 (4.77)
Delta	431.69 (2.02)	--	-851.18 (-3.48)	45.23 (3.67)	0.067 (5.12)	--
Eastern	570.78 (2.69)	--	-1075.43 (-3.94)	66.26 (5.03)	--	0.376 (2.83)
National	144.72 (1.93)	--	-492.67 (-7.06)	33.76 (8.00)	0.093 (4.93)	7.98 (3.16)
Northwest	303.39 (4.23)	162.96 (1.90)	-684.63 (-6.50)	62.96 (12.22)	0.060 (3.37)	0.362 (5.28)
TWA	751.92 (3.48)	--	-1807.71 (-7.77)	112.89 (7.16)	--	--
United	2335.19 (6.99)	--	-3682.68 (-8.75)	240.80 (7.79)	0.061 (6.38)	--
Western	215.15 (2.38)	--	-391.54 (-4.73)	27.01 (5.34)	0.043 (4.84)	--

* Log-linear equation

$$\begin{aligned}
 (b) \quad \text{LOG}(\text{PRFT}) &= - 3.79 + 5.08 \text{ LOG}(\text{YLD}) - 0.98 \text{ LOG}(\text{LEVGE}) \\
 &\quad (2.53) \quad \quad \quad (-4.12) \\
 &\quad + 0.43 \text{ LOG}(\text{RPMS}) + 0.37 \text{ LOG}(\text{PRMNS}) \\
 &\quad (2.24) \quad \quad \quad (4.77) \\
 C_p &= 5.00 \quad F = 41.55 \quad R^2 = 0.92 \quad \bar{R}^2 = 0.90
 \end{aligned}$$

In the linear model, both the overall goodness of fit was poor and the coefficient signs for advertising and average cost were contrary to expectation. Furthermore, yield was not significant in explaining changes in profitability. Advertising has been omitted entirely from the log-linear model, and the results are much improved.

4.4 Specification 4

The success with the log-linear model form for Continental under the previous specification suggested avenues for further research.

As stated previously, in order to convert the data to log form it is necessary for positive values to appear in each year. Unfortunately, this was only the case for the dependent variable (PRFT) for Braniff, Continental and Delta. No problem was encountered with independent variables. The other airlines incurred losses in the following years:

AA	1970, 1973, 1975
EA	1960, 1961, 1962, 1963, 1973, 1975
NA	1959, 1960, 1961, 1970
NW	1972

TW 1957, 1958, 1961, 1970, 1971, 1973, 1974, 1975

UA 1970, 1975

WA 1969, 1975

By changing the definition of profitability to exclude depreciation from total costs, a positive value was obtained for all airlines in every year (except for National in 1970 due to a long and damaging strike and American and TWA in 1975).

Profitability (PROF) = transport revenues - operating costs + depreciation. This revised definition of profitability represents a measure of internal cash flow which would be a major determinant of both capital investment expenditures and the ability of the firm to obtain further outside finance. A number of studies have used similar measures in explaining investment expenditure.⁶

The independent variables remained unchanged from the previous specification, other than dropping advertising expenditures.

$$\text{Model form: } y = \beta_0 x_1^{\beta_1} \cdot x_2^{\beta_2} \cdot x_3^{\beta_3} \dots x_m^{\beta_m} + \epsilon'$$

$$\text{Log transformation: } \log y = \log \beta_0 + \beta_1 \log x_1 + \beta_2 \log x_2 + \dots \epsilon$$

4.4.1 Individual Airline Results

A comparison of Table 4.5 with the previous results shows a marked improvement in \bar{R}^2 . Other than TWA which will be discussed below, \bar{R}^2 ranged

TABLE 4.5 TABLE OF COEFFICIENTS AND t-RATIOS

$$\text{PROF} = b_0 \text{YLD}^{b_1} \cdot \text{AVCOST}^{b_2} \text{LFA}^{b_3} \text{RPMS}^{b_4} \text{RPMNS}^{b_5} \text{LEVGE}^{b_6}$$

	YLD	AVCOST	LFA	RPMS	RPMNS	LEVGE	\bar{R}^2
American	5.84 (8.20)	-6.39 (-12.87)	4.65 (9.02)	0.76 (12.01)	--	--	0.97
Braniff	--	-1.18 (-2.23)	3.54 (3.91)	1.32 (13.57)	--	--	0.96
Continental	2.70 (3.35)	--	--	0.69 (9.00)	0.19 (6.09)	-0.44 (-4.64)	0.97
Delta	5.41 (8.42)	-4.53 (-10.21)	3.63 (11.07)	0.97 (28.19)	--	--	0.996
Eastern	4.37 (2.15)	-6.38 (-4.51)	5.50 (4.41)	1.20 (7.33)	--	--	0.90
National	8.44 (3.00)	-6.76 (-5.07)	5.44 (2.97)	0.54 (1.71)	--	--	0.90
Northwest	3.67 (3.58)	-4.33 (-6.44)	3.19 (6.80)	1.07 (9.75)	--	--	0.95
TWA*	670.3 (2.42)	-1603.3 (-5.37)	81.2 (3.49)	--	0.25 (2.16)		0.74
United	9.66 (4.62)	-9.19 (-5.48)	8.72 (4.27)	--	0.40 (7.11)	0.78 (2.38)	0.85
Western	5.37 (4.86)	-5.28 (-7.49)	4.46 (5.65)	0.77 (10.58)	0.12 (2.52)	--	0.96

* Linear model.

from 0.850 for United to 0.996 for Delta. Yield was significant in every model except Braniff. All coefficient signs were correct and multicollinearity was very similar to the results of the previous specification (3). For forecasting purposes, then, the equations appear at a first glance more than satisfactory.

TWA

After obtaining unsatisfactory results in running the data for TWA in log form (omitting 1975), it was decided to revert to the linear form with every year included. The goodness of fit of the final equation was still well below the other airlines ($\bar{R}^2 = 0.74$), but no further improvement was possible. Possible reasons for those results are:

- (a) TWA's large international operations
- (b) Cargo operations not included explicitly in the model

Analysis of Individual Variables

One of the advantages of the log-linear form is the comparability of coefficients. If other variables are held constant, it can be easily observed from the table that a 1% increase in yield has a very much greater impact on profitability for United than Continental.

YLD 1% yield increase produced following increase in profitability:

	<u>%</u>
United	10
National	8
American	6
Delta	5
Western	5

Eastern	4
Northwest	4
Continental	3

AVCOST 1% decrease in average costs produced following increase in profits:

	<u>%</u>
United	9
National	7
American	6
Eastern	6
Western	5
Delta	5
Northwest	4
Braniff	1

Load Factor 1% increase in load factor produced following increase in profits:

	<u>%</u>
United	9
Eastern	6
National	5
American	5
Western	4
Delta	4
Braniff	4
Northwest	3

Traffic 1% increase in scheduled traffic produced following increase
in profits:

	<u>%</u>
Braniff	1.3
Eastern	1.2
Northwest	1.1
Delta	1.0
Western	0.8
American	0.8
Continental	0.7
National	0.5

Multicollinearity Strong relationships between independent variables seriously impair the ability of the model to explain changes in the dependent variable by changes in each of the independent variables, individually. From this point of view, the best equations were for Continental, Northwest and, to a lesser extent, TWA, National and Delta, where multicollinearity was least in evidence.

Yield and average cost were positively correlated in many cases, and scheduled traffic and load factor negatively correlated. The highest single correlation coefficient (r) was 0.94 for Eastern's yield and average cost and -0.84 for Braniff's traffic and load factor.

References

1. See Kmenta, J., Elements of Econometrics, New York, Macmillan Co., 1971, pp. 5151-516; or Wallace, T.D., and A. Hussain, "The Use of Error Component Models in Combining Cross Section with Time Series Data", Econometrica 37:172-178, 1969, for more detailed discussion of pooling data.
2. See G.S. Maddala, "The Use of Variance Components Models in Pooling Cross Section and Time Series Data", Econometrica 39:341-358, 1971.
3. See Daniel, C. and F. Wood, Fitting Equations to Data, New York, J. Wiley and Sons, 1971, pp. 86-87, for a detailed discussion of the C_p criteria.
4. See Kmenta, op. cit., pp. 508-510.
5. See Pindyck and Rubinfeld, Econometric Models and Economic Forecasts, New York, McGraw-Hill, 1976, pp. 108-110, for a discussion of the corrective techniques for autocorrelation.
6. See Evans, M.K., "A Study of Industry Investment Decisions", Review of Economics and Statistics, 49, No. 2, May 1967, pp. 151-164 and Dhrymes, P.J. and Kurz, M., "Investment Dividend and External Finance Behavior of Firms", in Determinants of Investment Behavior, New York, Columbia Press for NBER, 1967, pp. 427-467.

5. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this report has been to develop individual airline models for the ten U.S. trunk airlines which could be used for the analysis, forecasting and possibly the control of profitability. While one should conclude that the final models presented under specification 4 were found to be most suitable for forecasting, as well as having a very strong theoretical underpinning, some of the earlier specifications also gave results that had interesting implications.

At all stages in the work, variables have been added to or subtracted from the model according to both intuitive sense and also empirical results. Some of the variables eventually withdrawn, such as aircraft utilization and length of haul, although useful for management control purposes, did not at the aggregate or system level provide sufficient agreement with actual variations in the data. Others such as advertising and leverage fitted the data relatively well, but gave ambiguous results in terms of causation. All variables, both dependent and explanatory, which were used in the calibrations of the four model specifications, are listed in Table 5.1. Specification 1 was calibrated on quarterly data, 2 on both pooled (cross-sectional and time series) and cross-sectional alone data, and the remainder on annual data. Certain explanatory factors such as management quality are almost impossible to quantify. General administration costs were considered as a proxy with little success. Few would agree that management quality and continuity have not been vital factors in the profit performance

of both Delta and Northwest over the period of the study.

Perhaps the single most difficult problem from a statistical and interpretive point of view is the fact that many of the factors that are intuitively important in influencing profits, also exert influence on another factor. Otherwise referred to as multicollinearity, the pervasive presence of this condition seriously affected the estimated coefficients in many cases, although it also confirmed one's prior opinion that many of the factors important to a successful carrier are interrelated. As a statistical alternative, the technique of orthogonal polynomials should perhaps be tried to address this issue.

In order to further improve the model, the problem of simultaneity should also be addressed. Mentioned briefly in Section 4, the fact that several independent variables are also potentially a function of the dependent variable requires that additional structural equations should be specified. Not only would this deal with the causality issue, but it would also provide useful insights into factors that influence higher actual load factors or determine average costs. For example the preliminary results that actual load factor is negatively correlated with passenger complaints is one such observation. Techniques such as two-stage and three-stage least squares or simultaneous equations could be used to provide the additional, corrected estimates.

As with any statistical model, the results should not be taken as inviolate truths that can perfectly and effortlessly predict the operating profits of an airline. They can, however, be used to draw inferences concerning the influence of a given factor and as such provide a tool for

TABLE 5.1 SUMMARY OF VARIABLES TESTED

Variables	Spec. 1	Spec. 2	Spec. 3	Spec. 3	Final
<u>Dependent:</u>					
Profit margin	x				
Return on assets	x				
Return on equity	x				
Return on capital	x				
Operating profit		x	x	x	
Cash flow					x
<u>Explanatory:</u>					
Competition	x				
Length of haul	x				
Density	x				
Concentration	x				
Seasonality	x				
Yield	x	x	x	x	x
Utilization	x				
Equipment quality	x				
Management quality	x				
Labor productivity		x	x		
Advertising	x	x	x	x	
Debt service	x				
Liquidity	x				
Leverage	x		x	x	
Non-sched %		x	x	x	x
Load factor		x	x	x	x
Capacity		x			
Traffic		x	x	x	x
Costs		x	x	x	x
Breakeven L/F		x			
GNP		x			
Money supply		x			
Traffic growth		x			

management to be used in the evaluation of various decisions concerning the operation of the firm. Above all, the models can be used to generate forecasts of airline profitability, thereby providing aircraft manufacturers, regulatory authorities and others involved in the future of the air transport system with a useful guide to the future.

Background References for APPENDIX B

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APPENDIX C

THE HAT MATRIX

(See Hoaglin, D.C., and R.E. Welsch, "The Hat Matrix in Regression and ANOVA", Harvard University and MIT, January 1977.)

Recalling that estimates of β , $\hat{\beta}$, are defined as

$$\hat{\beta} = (X^T X)^{-1} X^T Y$$

and

$$\hat{Y} = \hat{\beta} X$$

so that $\hat{Y} = X(X^T X)^{-1} X^T Y$

and the hat matrix, H , $= X(X^T X)^{-1} X^T$

By calculating the diagonal elements of the H matrix it is possible to identify points that are significantly influencing the fit.

As an approximation, these diagonal elements, h_i , can be obtained as follows

$$h_i = 1 - \frac{r_i}{r_i^*}$$

where r_i = least squares residual

r_i^* = predicted residual

Using $\frac{2P}{N}$ as a cutoff point (P = number of parameters, N = number of observations), "high" leverage points can be identified.

It is also useful to examine the residuals themselves in order to detect outliers. However, as Welsch and Hoagland again point out, in order to allow

for differences in the variances of the residuals, one should look at the standardized residuals where

$$r_i' = \frac{r_i}{(S \sqrt{1-h_i})}$$

r_i' = standardized residual

r_i = least squares residual

S^2 = residual mean square

h_i = diagonal element of hat matrix.